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AN INVESTIGATION OF ION REMOVAL FROM WATER AND WASTEWATER

R. J. Starkey, Jr., et al

General Electric Company

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August 1973

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Three standardized techniques (capillary membrane dialysis, alumina adsorption, alum/ polyelectrolyte coagulation) have been compared under laboratory conditions to determine their relative effectiveness in removing a broad spectrum of nutrients, cations, and anions from freshly collected samples of stream water and wastewater effluent (secondary and tertiary).

Of these alumina adsorption was highly effective in removal of phosphorus, inorganic carbon, as well as most cations with concomitant reduction of specific conductance and hardness. High Kjeldahl and ammonia nitrogen removal efficencies of alumina were only observed in samples of wastewater in which pre-treatment concentrations were relatively high. Dissolved solids content and pH of alumina treated samples were consistently observed to increase.

Dialysis occupied an intermediate position in respect to cation removal, but produced results equivalent to alumina adsorption in respect to inorganic carbon. Failure to significantly reduce organic carbon concentrations was attributed to its association with macromolecules having a molecular weight greater than 5000 (the cutoff of the cellulose membrane under consideration). Superiority of dialysis in removal of sodium, potassiu, chloride, nitrate-nitrte, boron, and dissolved solids is reported. Coagulation was effective in removing phosphorus from all waters but was highly ineffective in respect to all other parameters tested.

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AN INVESTIGATION OF ION REMOVAL FROM WATER AND WASTEWATER

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Contract No. 68-01-0904
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ABSTRACT

Three standardized techniques (capillary membrane dialysis, alumina adsorption, alum/polyelectrolyte coagulation) have been compared under laboratory conditions to determine their relative effectiveness in removing a broad spectrum of nutrients, cations, and anions from freshly collected samples of stream water and wastewater effluent (secondary and tertiary).

Of these alumina adsorption was highly effective in removal of phosphorus, inorganic carbon, as well as most cations with concomitant reduction of specific conductance and hardness. High Kjeldahl and ammonia nitrogen removal efficiencies of alumina were only observed in samples of wastewater in which pre-treatment concentrations were relatively high. Dissolved solids content and pH of alumina treated samples were consistently observed to increase.

Dialysis occupied an intermediate position in respect to cation removal, but produced results equivalent to alumina adsorption in respect to inorganic carbon. Failure to significantly reduce organic carbon concentrations were attributed to its association with macromolecules having a molecular weight greater than 5000 (the cutoff of the cellulose membrane under consideration). Superiority of dialysis in removal of sodium, potassium, chloride, nitrate-nitrite, boron, and dissolved solids is reported. The latter is of particular interest as it provides an interesting method of investigating the effects of toxicants in stream water and wastewater effluent which could compound the problem of analyzing algal assay data.

Alum/polyelectrolyte (Betz #1150) proved to be effective in removing phosphorus from all waters tested, but was highly ineffective in respect to all other parameters tested. Coagulated samples were shown to contain potassium and sulfate in excess of controls and increased conductance.

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SECTION I

CONCLUSIONS

Water and wastewater effluent can be processed in the laboratory after 0.45 μ filtration to compare the effectiveness of capillary membrane dialysis; alumina adsorption; and coagulation in removing nutrients, cations, and anions as well as modifying parameters as specific conductance, total alkalinity, pH, and dissolved solids.

With minor exceptions coagulation with alum (aluminum potassium sulfate) plus a polyelectrolyte (Betz #1150) was generally ineffective except for the removal of high concentrations of phosphorus. Alum contributed sulfate and potassium to samples in excess of control values; and increased conductivity, hardness, and total alkalinity in most cases.

Alumina adsorption and dialysis demonstrated equivalent efficiency in removing total carbon from water and wastewater (86% and 81%, respectively), whereas the alum/polyectrolyte (Betz #1150) was only 13% effective.

The total carbon content of all waters consisted primarily of an inorganic fraction which is attributed to carbonate carbon derived from salts of calcium, magnesium, and sodium. Evidence for this is based on a reduction in the concentration of these cations and total alkalinity which parallel inorganic carbon removal.

Organic carbon removal was limited in all cases, although it is concluded that coagulation was the least effective on a qualitative basis. Failure of dialysis to remove greater concentrations of organic carbon is attributed to their association with macromolecules, i.e., > 5000 MW, which are excluded by the cellulose membrane under consideration.

Phosphorus (soluble) was most efficiently removed by alumina adsorption and to a lesser extent by coagulation. Of the three methods dialysis was the most unreliable.

With minor exceptions alumina contributed nitrogen to stream water samples. This is due to organic and inorganic nitrogen being loosely bound to alumina and readily eluted by addition of subsequent samples to the column.

With higher concentrations of Kjeldahl nitrogen, as found in the Phoenixville wastewater effluent (15-29 ppm), alumina successfully removed 92-97% and dialysis 84-90%. For the same waters treatment by coagulation resulted in values exceeding controls to a maximum removal of 40%. The same trend was seen with ammonia nitrogen.

Calcium and magnesium were removed from all waters by alumina adsorption in the range of 95-99% and 92-99%, respectively. In comparison dialysis removed 36-85% calcium and 33-81% of magnesium. Variable results occurred with coagulation ranging from concentrations exceeding controls to a maximum of 53%.

Alumina adsorption removed 75-92% of potassium from stream water and 90-98% from wastewater effluent. In comparison dialysis removed 28-90% from stream water and 50-85% from wastewater.

Boron was most effectively reduced by dialysis and to a lesser extent b alumina adsorption. Coagulation produced highly variable results and was generally unreliable.

Alumina removal of silicon from wastewater effluent fell in the range of 91-98% whereas dialysis did not exceed 49-76%.

Dialysis was the method of choice for removing sodium; alumina and coagulation produced highly variable results.

Of the anions tested sulfate was effectively removed by alumina (4-99%) and to a lesser extent by dialysis (11-73%). Coagulation, as previously alluded to was ineffective. Dialysis was superior for removal of chloride ions (as high as 84% with stream water and 88% for treatment plant effluent); coagulation and alumina demonstrated second and third level activity, respectively.

Dialysis was particularly effective in reducing specific conductance (82% in stream and 75% wastewater samples). In contrast this parameter was generally elevated following alumina or coagulation treatment.

Hardness was most efficiently reduced by alumina (96-99%) and to a lesser extent by dialysis (23-81%). Coagulation more often than not increased hardness.

Total alkalinity reduction by dialysis reached 71-89% in stream water and 62-81% in wastewater effluent. In comparison this ranged from 6-25% and 6-35%, respectively, in waters treated by coagulation. Alumina occupied an intermediate position with values exceeding controls to a maximum reduction of 84% recorded.

Hydrogen ion concentration dropped in all cases following dialysis and to a lesser extent after coagulation. In contrast the pH of alumina treated samples increased due to the alkaline condition of the column.

Dissolved solids were most effectively removed by dialysis (71-75% with Phoenixville samples and 42-67% for those from the Hatfield plant). Alumina contributed to the dissolved solids loading of many samples as a result of early breakthrough of less tenaciously bound species.

Coagulation was found to be very unpredictable and for the most part increased dissolved solids above control values.

Dialysis provides a method of experimentally treating waters to remove nutrients, cations, and anions without actively introducing other chemicals. It is furthermore suggested that dialysis with capillary membranes having cutoffs at different molecular weights would provide an interesting approach to investigating potentially toxic materials in stream water and wastewater effluents which could influence the bottle algal assay.

Of the three methods evaluated coagulation appears to be the most practical route for developing a basal medium for the algal assay as long as the elevation of sulfate, hardness, potassium, and conductivity do not interfere with the addition of incremental quantities of phosphorus containing salts. Solubilization would have to be carefully monitored to preclude precipitation or adsorption of a fine precipitate to suspended particles. Similarly potential changes in pH and/or buffering capacity must be considered in relation to the test alga if growth dynamics are to be suitably interpreted for a given sample of test water. This can only be determined experimentally if the coagulation method of preparing a basal medium is to be considered for routine assessment of the eutrophication process or monitoring a waste treatment plant effluent.

Based upon this study capillary membrane dialysis occupies an intermediate position regarding the complexity of reconstituting treated waters, although its main utility appears to be as a tool in investigating the role of high molecular weight dissolved solids on the assay system. As alluded to previously one of the most important factors in favor of dialysis is its passive nature, i.e., it does not add any constituents to the test waters as reported for coagulation and alumina adsorption treatment.

Alumina adbsorption *per se* is analogous to a "shot gun" approach in that a broad spectrum of materials are removed with phosphorus being the most notable, but is also associated with concurrent increase of pH, sodium, and dissolved solids. Reconstitution of such waters would be very time consuming if all but the limiting nitrient of choice were to be brought back to their original concentration without precipitation and/or complexing. Furthermore, based on the propensity of activated alumina for metals it would be particularly difficult to reconstitute trace metals. The latter would be especially true if the concentration was near the limit of resolution for atomic adsorption spectrophotometry.

The suitability of each method in preparing a basal medium is summarized as follows:

METHOD	ADVANTAGE	DISADVANTAGE	RECOMMENDATIONS
COAGULATION WITH ALUM + POLYELECTROLYTE (BETZ #1150)	1. Minimizes removal of cations/anions and nutrients other than phosphorous.	1. Relatively slow (50 minutes to prepare sample). 2. Contributes sulfate, potassium, dissolved solids to water. 3. Phosphorus removal efficiency < alumina, adsorption > dialysis.	1. Investigate increase of sulfate etc. on assay system. 2. Determine how easily incremental of phosphorous can be added to treated waters. 3. Compare response of test alga in coagulated/ reconstituted (phosphorus) waters with equivalent inocula in synthetic medium.

METHOD	**ADVANTAGE**	**DISADVANTAGE**	**RECOMMENDATIONS**
ALUMINA ADSORPTION	1. Highly efficient removal of phosphorus. 2. Very fast: 1-2 liters treated in 10 mins.	1. Removes broad spectrum of cations/anions. 2. Reconstitution complicated by problems of solubility/ complexing. 3. Removal of trace metals which may be difficult to confirm.	1. Give very low priority to this method for preparation of basal medium unless problems of reconstitution/ analytical work load can be overcome.

METHOD	ADVANTAGE	DISADVANTAGE	RECOMMENDATIONS
CAPILLARY MEMBRANE DIALYSIS	1. Cellulos acetate membranes significantly reduced dissolved solids 5000 MW. 2. Occupies a relative intermediate position between coagulation and alumina adsorption in regard to cation/anion/nutrient removal. 3. Method is strictly passive: does not add anything to treated waters.	1. Test waters must be prefiltered to preclude clogging membranes. 2. Waters would be difficult to reconstitute. 3. Precipitation/complexing incremental addition of P source must be precluded.	1. Versatility of method can only be exploited by evaluating different types of membranes and molecular weight cutoffs. 2. Emphasis should be placed on using membranes to investigate toxicants in dissolved solids which could stimulate or supress growth of the test alga in natural and synthetic media. 3. Other parameters to be investigated in-depth include temporal and pressure optima definition.

SECTION II

RECOMMENDATIONS

Based on the significant reduction of dissolved solids (~ 5000 MW) achieved with capillary membrane dialysis it is recommended that advanced studie be conducted to determine the effect of removing high and low molecular weight fractions prior to bottle test algal assay. This would aid in confirming the presence of trace toxicants in test waters which could have an adverse effect on the test alga and compound the problem of assay data analysis and interpretation *per se*.

The proposed study would include assaying natural (secondary and tertiary effluents) and synthetic waters *before* and *after* dialysis with membranes having molecular weight cutoffs of 200, 5,000, and 30,000. Each assay would be accompanied by comprehensive chemical analysis (pre and post dialysis) with reconstitution of test waters as required.

The following details a work statement and program schedule for the proposed study.

Task 1 - Obtain Candidate Dialysis Membranes of Molecular Weight Cutoff

(A) 200
(B) 5,000
(C) 30,000

Task 2 - Prepare Chemically Defined Medium

(A) Prepare chemically defined medium as used by the Eutrophication Branch, Environmental Protection Agency, Corvallis, Oregon, for the bottle algal assay. Determine "standard" growth response of *S.capricornutum* Printz with this medium to establish control curves.

(B) Dialyzed (pre-analyzed) chemically defined medium to determine fractions removed by capillary membranes having a molecular weight cutoff of 200, 5,000, and 30,000.

(C) Based on chemical analyses of dialyzed samples prepared in (B) each is to be reconstituted, i.e., as determined by difference analysis, and assayed against undialyzed chemically defined medium.

Task 3 - Algal Assay of Secondary and Tertiary Wastewater Effluent

(A) Ten samples each are to be obtained on different dates from the following treatment plants:

1. Phoenixville - Secondary
2. Hatfield - Tertiary

(B) Each is to be processed, analyzed and assayed as follows:

1. Pre-dialysis analysis (following 0.45 μ filtration)
2. Pre-dialysis algal assay
3. Dialysis:
   (a) Molecular weight cutoff: 200
   (b) Molecular weight cutoff: 5,000
   (c) Molecular weight cutoff: 30,000
4. Post dialysis analysis of waters dialyzed according to 3.
5. Reconstitution of dialyzed waters based on different analysis.
6. Algal assay of dialyzed (reconstituted) samples.

Task 4 - Algal Assay of Secondary and Tertiary Wastewater Effluent Spiked with Low and High Molecular Weight Toxicants

Task 3 is to be repeated except that an additional set of samples is to be spiked with known concentrations of low and high molecular weight toxicants to verify the efficacy of dialysis on removing these from test waters.

Choice of toxicants is to be mutually agreed upon by the EPA Project Officer and General Electric Company Program Manager.

Task 5 - Data Reduction and Analysis

(A) A Fortran IV program is to be written to expedite analytical calculations and correlation studies.

(B) Data is to be analyzed to determine the significance of low and high molecular weight fractions in test waters in influencing the standard algal bottle assay.

Task 6 - Deliverables

The following deliverables are to be made to the Eutrophication Branch, Environmental Protection Agency, National Environmental Research Center, Corvallis, Oregon:

(A) 11 Monthly status reports.
(B) Oral report of program status at conclusion of 6th month.
(C) Final report two months following completion of contract.

Schedule

Study is to be conducted over a 12 month period exclusive of the final report.

SECTION III

INTRODUCTION

This report provides a detailed account of all work carried out from 1 July 1972 to 1 July 1973 under Contract #68-01-0904, granted to the General Electric Company, Re-Entry and Environmental Systems Division, Philadelphia, Pennsylvania, by the U.S. Environmental Protection Agency, National Environmental Research Center, Corvallis, Oregon.

The primary objective of the program was to evaluate three methods (capillary membrane dialysis, coagulation, alumina adsorption) for selectively removing nutrients, cations, and anions from water and wastewater. A comparison of a biological system with physico-chemical techniques was originally proposed, but was abandoned with concurrence of the Project Officer in favor of using alum in combination with a polyelectrolyte based on its use in the tertiary treatment facility of the U.S. Environmental Protection Agency at Ely, Minnesota.

The organization of this report discusses the basic rationale for conducting the study; equipment and methods used in the treatment of water derived from three streams in the Schuylkill River basin and effluents of two waste treatment (1 secondary and 1 tertiary) plants; analytical methodology; and data reduction and analysis.

SECTION IV

PURPOSE AND NEED OF THE STUDY

Development of a standarized algal assay[1,2,3,4] has provided a practical means of investigating and solving problems related to eutrophication. Based on established procedures the growth of a test alga as Selenastrum capricornutum Printz in a sterile synthetic nutrient medium is compared with growth of an equivalent inoculum in a sterile sample of test water under identical conditions of incubation and illumination. The slope of the standard curve is compared with that of the unknown to assess the eutrophication problem in a given body of water or provide an index of the effectiveness of treatment methods.

This has created a problem in data analysis since the aforementioned synthetic medium per se contains macro- and micro-nutrients, including trace metals, which may be deficient in some test waters and/or in excessive concentrations in others (Table 1). Thus, differences in the slope of the unknown assay curve in comparison to the standard may not only be due to a limiting nutrient such as phosphorus, but a compound effect attributed to stimulation or repression of metabolic processes by other chemicals which cannot be readily compensated for from one assay to another. In addition, waters to be evaluated may also contain high concentrations of dissolved solids (low and high molecular weight), including organic[5] and inorganic toxicants, which are capable of influencing assay results by virtue of algicidal or algistatic activity.

A potential approach to solving the problem has been suggested by the Eutrophication Branch, National Environmental Research Center, Corvallis, Oregon, in which the synthetic assay medium[3] is substituted with a basal medium prepared from an aliquot of the test water (Figure 1). In this scheme the freshly collected water is chilled (4°C) to retard microbial growth, vaccum filtered through an unlined 0.45 μ membrane filter, divided into two containers, and autoclaves at 15 psig for 30 minutes. One container is stored at 4°C in the dark until required for the assay and the other processed to produce a basal medium. The optimum method would allow nutrients, cations, and anions to be removed individually or collectively without altering the percentage composition of the other constituents. Treated water would be analyzed to confirm the concentration of nutrients removed and sub-divided, for example, into four equal volumes. Incremental concentrations of the nutrients removed would be added to three of the containers from sterile stock solutions of each nutrient prepared from reagent grade chemicals. The fourth container would serve as a blank but would have its volume suitably adjusted with sterile distilled water.

Each container of the reconstituted medium and blank plus two of the test samples would be inoculated with 10^3/ml Selenastrum capricornutum

Printz, or other appropriate test organisms, incubated, and processed according to standard assay procedures[2].

It is the intent of this study to investigate the feasibility of methods which would be suitable for selectively removing nutrients, cations, and anions, individually or collectively from water and wastewater for the purpose of preparing a basal algal assay medium.

Table 1

Comparison of Macro- and Micro Nutrients of Synthetic Algal Assay Medium[3] With Those Typically Found in Trout Run French Creek, Valley Creek, of the Schuylkill River Basin and Effluents of the Phoenixville (Secondary) and Hatfield (Tertiary), Pennsylvania Waste Treatment Plants.

CONSTITUENT	CONCENTRATION PARTS PER MILLION					
	SYNTHETIC MEDIUM	TROUT RUN	FRENCH CREEK	VALLEY CREEK	PHOENIXVILLE	HATFIELD
Macronutrients						
NO_3-N	4.2	1.91	1.47	2.23	0.13	0.05
Total PO_4-P	0.186	0.009	0.029	0.159	7.9	0.216
Mg	2.904	15.5	**	19.5	12.0	9.2
S	1.911	← SEE BELOW UNDER $SO_4^=$ →				
C-Inorganic	2.143	23	7.3	26.8	43.2	50.8
Ca	1.202	35	17.5	62	80	87
Na	11.001	5.4	10.1	15.7	66	60
K	0.469	1.76	1.5	2.1	16	14
Micronutrients						
B	0.03246	0.06	0.11	0.18	0.86	0.90
Mn	1.115	0.05	0.05	0.05	0.05	0.05
Zn	0.01569	0.04	0.02	0.02	0.08	0.04
Co	0.00035	0.1	0.1	0.1	0.1	0.1
Cu	0.00004	0.1	0.1	0.1	0.1	0.1
Mo	0.00287	**	**	**	**	**
Fe	0.03305	0.1	0.1	0.1	0.28	0.1
Nutrients, Minerals, Physico-Chemical Parameters Not Specified for Synthetic Medium						
Silica	-----	0.06	5.24	0.56	6.42	3.16
SO_4	-----	18.1	33.5	34.2	119	357
NO_2-N	-----	0.004	0.008	0.012	0.087	0.105
NH_3-N	-----	0.13	0.07	0.03	22.8	64.7
Kjeldahl N	-----	0.40	0.27	0.28	31.4	70.2
Specific Conductance***	-----	340	220	500	825	1530
Total Alkalinity	-----	93.4	26.9	146	177	213
Cl	-----	**	**	**	**	**
Total Solids	-----	186	130	350	406	566
Dissolved Solids	-----	**	132	463	650	668
Total Carbon	-----	27.5	11.1	33.6	65.3	72.6
Organic Carbon	-----	4.5	3.8	6.8	22.1	21.8
Hardness EDTA	-----	115.4	48.0	168	156	261

* See Appendices I.(All stream and plant effluents collected April 1973)

** Not tested.

*** Expressed as μ mhos/cm.

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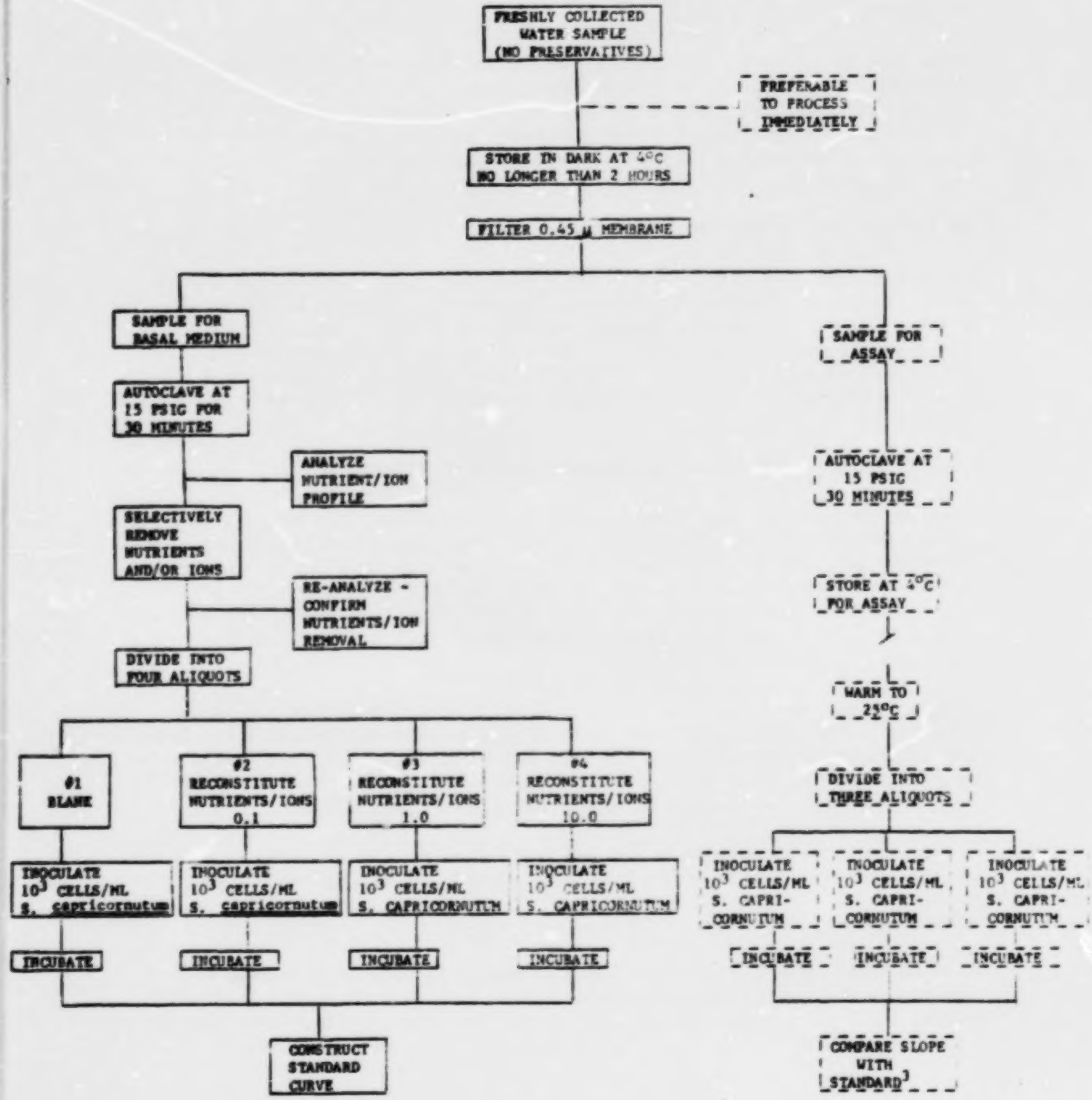
Figure 1

Idealized Method of Preparing Basal Medium for Bottle Algal Assay Procedure


FRESHLY COLLECTED WATER SAMPLE (NO PRESERVATIVES)
PREFERABLE TO PROCESS IMMEDIATELY
STORE IN DARK AT 4°C NO LONGER THAN 2 HOURS
FILTER 0.45 μ MEMBRANE
SAMPLE FOR BASAL MEDIUM
SAMPLE FOR ASSAY
AUTOCLAVE AT 15 PSIG FOR 30 MINUTES
ANALYZE NUTRIENT/ION PROFILE
AUTOCLAVE AT 15 PSIG 30 MINUTES
SELECTIVELY REMOVE NUTRIENTS AND/OR IONS
RE-ANALYZE - CONFIRM NUTRIENTS/ION REMOVAL
STORE AT 4°C FOR ASSAY
DIVIDE INTO FOUR ALIQUOTS
WARM TO 25°C
DIVIDE INTO THREE ALIQUOTS
#1 BLANK
#2 RECONSTITUTE NUTRIENTS/IONS 0.1
#3 RECONSTITUTE NUTRIENTS/IONS 1.0
#4 RECONSTITUTE NUTRIENTS/IONS 10.0
INOCULATE 10^3 CELLS/ML S. capricornutum
INOCULATE 10^3 CELLS/ML S. capricornutum
INOCULATE 10^3 CELLS/ML S. CAPRICORNUTUM
INOCULATE 10^3 CELLS/ML S. CAPRICORNUTUM
INOCULATE 10^3 CELLS/ML S. CAPRI-CORNUTUM
INOCULATE 10^3 CELLS/ML S. CAPRI-CORNUTUM
INOCULATE 10^3 CELLS/ML S. CAPRI-CORNUTUM
INCUBATE
INCUBATE
INCUBATE
INCUBATE
INCUBATE
INCUBATE
INCUBATE
CONSTRUCT STANDARD CURVE
COMPARE SLOPE WITH STANDARD

SECTION V

EXPERIMENTAL PROCEDURES

DERIVATION OF WATER SAMPLES

Three streams (Trout Run, Valley Creek, and French Creek) in the Schuylkill River Basin of Southeastern Pennsylvania were selected for this study based upon a preliminary survey of physico-chemical characteristics; accessibility; and proximity to the laboratory. Sampling sites are documented in Table 2 and identified on a map of the river basin (Figure 2).

DERIVATION OF WASTEWATER SAMPLES

Effluents were collected from a secondary (Phoenixville, Pennsylvania) and a tertiary[6] (Hatfield Township, Pennsylvania Municipal Authority Advanced Waste Treatment Facility) treatment plant. Data pertinent to these are summarized in Table 3. Selection was based upon the availability of secondary and tertiary effluents within a convenient distance of the laboratory to minimize delays in analyzing and processing samples (Figure 2).

COLLECTION AND PROCESSING OF SAMPLES PRIOR TO TREATMENT

Samples for a given experimental run were collected in four (4) liter Cubitainers$^{(R)}$ (Hedwin Corporation, Baltimore, Maryland) equipped with polypropylene closures at each of the stream sites within 45 minutes - 1 hour and immediately returned to the laboratory. Plant effluents were also collected in the same type of container but on an independent schedule to preclude a backlog of analytical work or conflict with other programs.

Samples were recovered from stream or effluents with a 900 ml (Tri-pour$^{(R)}$) disposable beaker and transferred to the Cubitainer$^{(R)}$. Care was taken to insure complete filling and elimination of dead space prior to sealing with the closure. Each container was appropriately identified with the location, date, and time of collection.

Temperature adjustment to ~ 4°C was initiated at the collection site by placing the containers in an insulated chest containing water ice.

SAMPLE FILTRATION

Upon receipt at the laboratory approximately half of the sample (5-6 liters) collected at each site was vacuum filtered through a plate (no grids) 0.45 μ membrane filter (Millipore Corporation, Bedford, Mass.) into a two liter flask which had previously been washed (without

Table 2

Stream Sampling Sites

STREAM	LOCATION
French Creek	Rapps Bridge
Valley Creek	Covered Bridge
Trout Run	Thomas Road

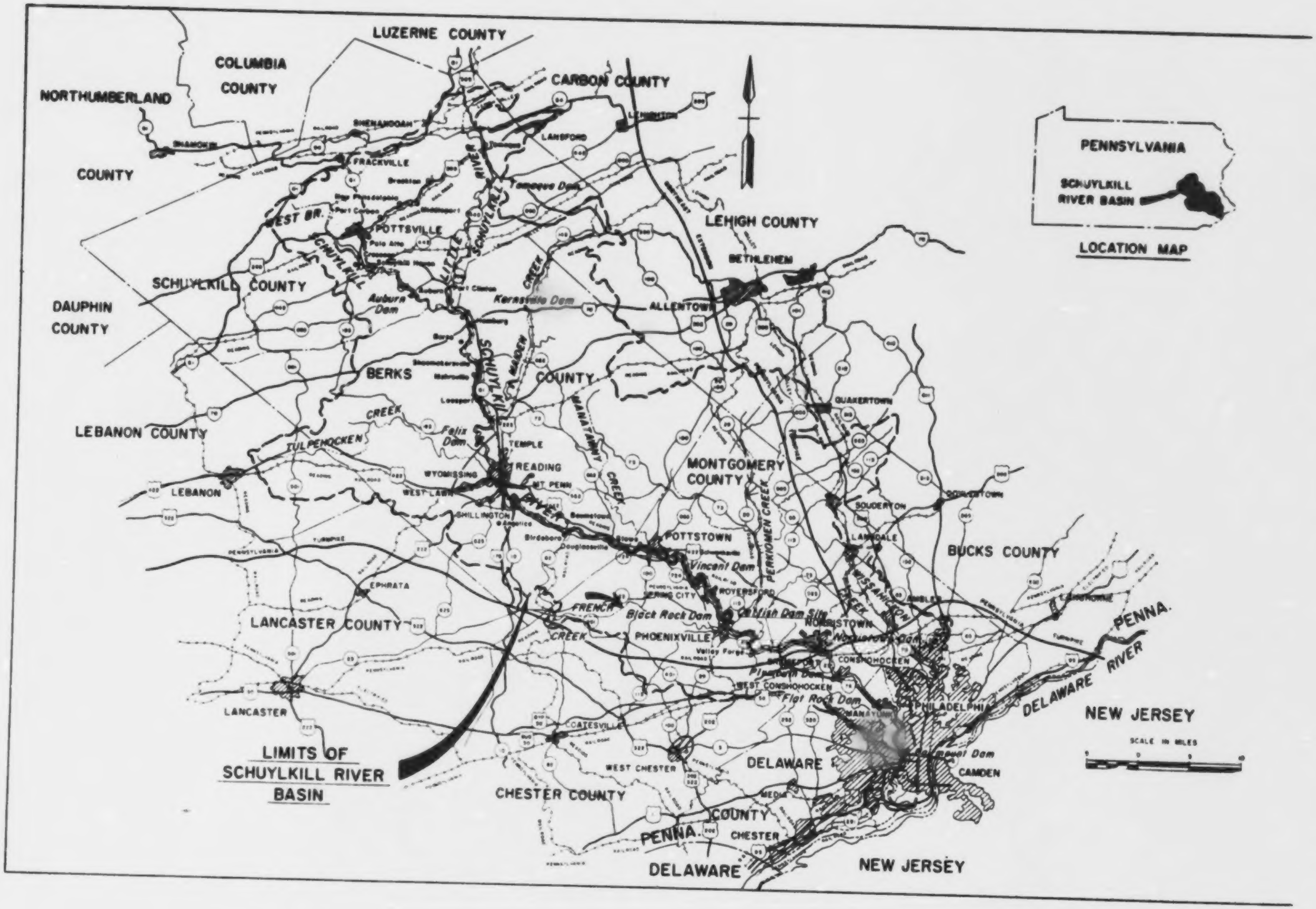

LUZERNE COUNTY
COLUMBIA COUNTY
NORTHUMBERLAND COUNTY
CARBON COUNTY
PENNSYLVANIA
SCHUYLKILL RIVER BASIN
LOCATION MAP
LEHIGH COUNTY
BETHLEHEM
ALLENTOWN
SHENANDOAH
FRACKVILLE
LANSFORD
Tamaqua Dam
WEST BR.
POTTSVILLE
SCHUYLKILL
LITTLE SCHUYLKILL
SCHUYLKILL RIVER
SCHUYLKILL COUNTY
Auburn Dam
Kernsville Dam
DAUPHIN COUNTY
BERKS COUNTY
MAIDEN CREEK
QUAKERTOWN
LEBANON COUNTY
TULPEHOCKEN CREEK
Felix Dam
TEMPLE
READING
WYOMISSING
MT PENN
WEST LAWN
SHILLINGTON
LEBANON
MANATAWNY CREEK
MONTGOMERY COUNTY
PERKIOMEN CREEK
SOUDERTON
DOYLESTOWN
LANSDALE
BUCKS COUNTY
POTTSTOWN
Vincent Dam
ROYERSFORD
SPRING CITY
Black Rock Dam
Catfish Dam Site
FRENCH CREEK
PHOENIXVILLE
Valley Forge
NORRISTOWN
Norristown Dam
WISSAHICKON CREEK
CONSHOHOCKEN
WEST CONSHOHOCKEN
Plymouth Dam
Flat Rock Dam
MANAYUNK
PHILADELPHIA
Fairmount Dam
CAMDEN
PENNA.
DELAWARE RIVER
NEW JERSEY
SCALE IN MILES
0
5
10
EPHRATA
LANCASTER COUNTY
LANCASTER
LIMITS OF SCHUYLKILL RIVER BASIN
COATESVILLE
WEST CHESTER
CHESTER COUNTY
DELAWARE COUNTY
MEDIA
CHESTER
PENNA.
DELAWARE
NEW JERSEY

Figure 2: Schuylkill River Basin: French Creek, Valley Creek, and Trout Run sampling sites.

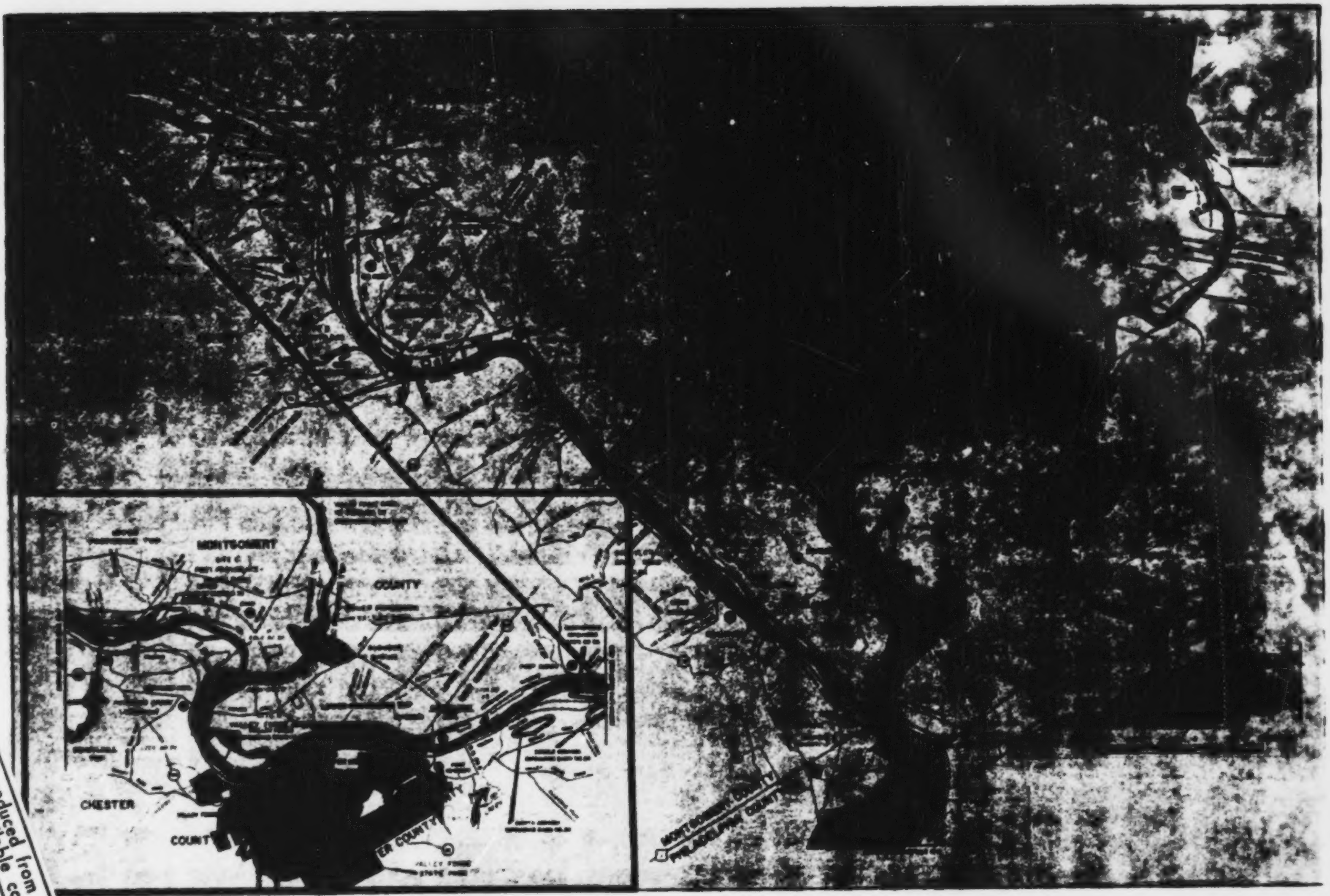

MONTGOMERY
COUNTY
CHESTER
COUNTY
ER COUNTY
VALLEY FORGE STATE PARK
MONTGOMERY COUNTY
PHILADELPHIA COUNTY

Figure 2. Schuylkill River Basin: French Creek, Valley Creek, and Trout Run sampling sites. (Continued)

Reproduced from best available copy.

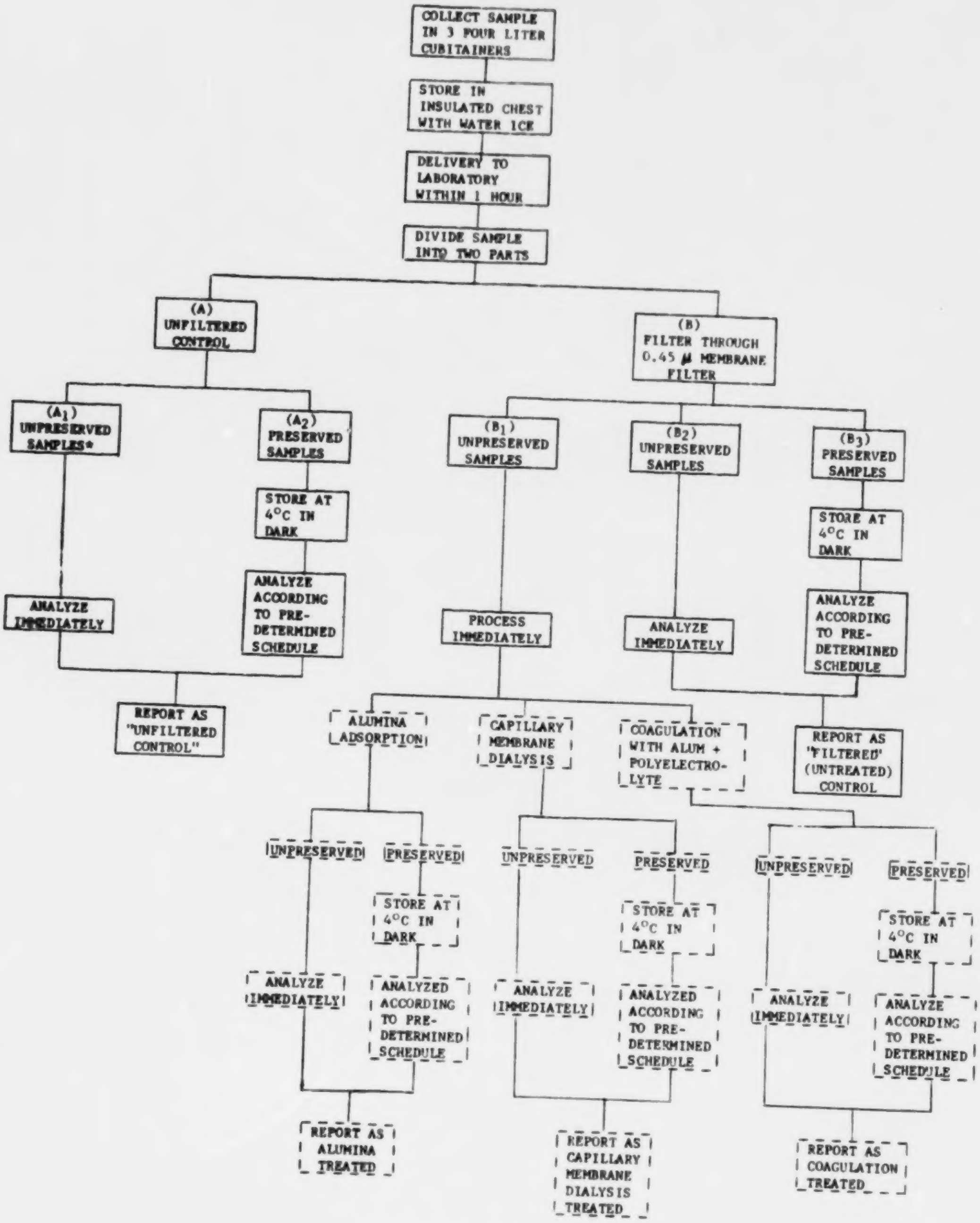
Table 3

Specifications of Waste Treatment Plants

PLANT	DRAINAGE BASIN	RECEIVING WATERS	TYPE	RATED CAPACITY	TREATMENT MODE SUMMARY
Phoenixville, Pa.	Schuylkill River	Schuylkill River	Secondary	6 mgd	Primary + Trickling Filter + Activated Sludge
Hatfield Township Municipal Authority Advanced Waste Treatment Facility[6]	Delaware River	Neshaminy Creek	Tertiary	3.6 mgd	Lime Treatment Raw Sewage at pH 9.5-10.5 Solids Recirculation to Primary to Conserve Chemicals Combined Bio-Oxidation & Nitrification Mixed Media Filtration

Figure 3

General Scheme For Processing and Analysis of Water and Wastewater Samples


COLLECT SAMPLE IN 3 FOUR LITER CUBITAINERS
STORE IN INSULATED CHEST WITH WATER ICE
DELIVERY TO LABORATORY WITHIN 1 HOUR
DIVIDE SAMPLE INTO TWO PARTS
(A) UNFILTERED CONTROL
(B) FILTER THROUGH 0.45 μ MEMBRANE FILTER
(A1) UNPRESERVED SAMPLES*
(A2) PRESERVED SAMPLES
(B1) UNPRESERVED SAMPLES
(B2) UNPRESERVED SAMPLES
(B3) PRESERVED SAMPLES
STORE AT 4°C IN DARK
STORE AT 4°C IN DARK
ANALYZE IMMEDIATELY
ANALYZE ACCORDING TO PRE-DETERMINED SCHEDULE
PROCESS IMMEDIATELY
ANALYZE IMMEDIATELY
ANALYZE ACCORDING TO PRE-DETERMINED SCHEDULE
REPORT AS "UNFILTERED CONTROL"
ALUMINA ADSORPTION
CAPILLARY MEMBRANE DIALYSIS
COAGULATION WITH ALUM + POLYELECTROLYTE
REPORT AS "FILTERED" (UNTREATED) CONTROL
UNPRESERVED
PRESERVED
STORE AT 4°C IN DARK
ANALYZE IMMEDIATELY
ANALYZED ACCORDING TO PRE-DETERMINED SCHEDULE
REPORT AS ALUMINA TREATED
UNPRESERVED
PRESERVED
STORE AT 4°C IN DARK
ANALYZE IMMEDIATELY
ANALYZED ACCORDING TO PRE-DETERMINED SCHEDULE
REPORT AS CAPILLARY MEMBRANE DIALYSIS TREATED
UNPRESERVED
PRESERVED
STORE AT 4°C IN DARK
ANALYZE IMMEDIATELY
ANALYZE ACCORDING TO PRE-DETERMINED SCHEDULE
REPORT AS COAGULATION TREATED

* SEE TABLE NO. 4

phosphate containing soaps), rinsed three times in deionized water, and dried at 100°C in a convection oven. Filters were operated with and without the benfit of glass-fiber pre-filters and replaced as flow rates diminished due to the accumulation of solids. Filtrates were added to previously unused Cubitainers(R), sealed, identified, stored in the dark at 4°C, or processed according to the flow chart outlined in Figure 3.

SAMPLE PRESERVATION

In all cases raw samples (unfiltered) and filtrates were further subdivided into two and three aliquots, respectively. One sample in each category (A_1-A_2 in Figure 3) was designated as being "unpreserved" and given priority for immediate analysis to minimize changes in concentrations of labile constituents. A second unpreserved filtered sample (Figure 3 B_1) was immediately sub-divided into three additional portions for treatment by alumina adsorption; capillary membrane dialysis; and coagulation.

Samples (A_2 and B_3) to be "preserved" were similarly sub-divided into smaller containers; identified; and treated with specific preservatives prepared from reagent grade chemicals according to standard U.S. Environmental Protection Agency procedures[5] (Table 4). These were stored in the dark at 4°C and analyzed within the recommended holding period.

Although mercuric chloride was a suitable preservative for nitrogen analysis, including Kjeldahl and nitrate/nitrite, it was found to interfere with low level phosphorus analyses. For this reason phosphorus was included among the test parameters of "unpreserved samples" (filtered and unfiltered) analyzed within a short period of being received in the laboratory. Samples for boron and silica analysis were preserved with sulfuric acid and those for metal cations with nitric acid.

EQUIPMENT AND METHODS OF TREATMENT

Equipment and methods for treatment of membrane filtered samples of water and wastewater by coagulation, capillary membrane dialysis, and alumina adsorption are to be described.

Requirements for filtered samples have been dictated by the capillary membrane system since particles $> 10\mu$ (see Appendix II) can be trapped and result in the development of a pressure differential. For this reason the decision was made to standardize all treatment processes by using membrane filtered samples.

Table 4

Preservation of Filtered and Unfiltered Samples *

ELEMENT **	PRESERVATIVE **	CONCENTRATION	MAXIMUM HOLDING PERIOD BEFORE ANALYSIS	REFERENCE
Metal Cations	HNO_3	5 ml/ liter	6 months	Methods for Chemical Analysis of Water & Wastes, U. S EPA
Nitrogen (All Forms)	$HgCl_2$	40 mg/ liter at 4°C	7 days	ibid, p3.
Boron	H_2SO_4	2 ml/ liter	7 days	-
Silicon	H_2SO_4	2 ml/ liter	7 days	-

*All samples stored/ preserved in Cubitainers(R) equipped with polypropylene closures.
**Reagent Grade

(A) Coagulation

Water Samples -

A 0.8 liter sample was added to a 1 liter beaker and mixed at 100 rpm with a Phipps-Bird* variable speed mixer (Figure 4). To this was added 20 ppm reagent grade alum (aluminum potassium sulfate) to achieve a final concentration of 100 ppm. Mixing was continued for 15 minutes and Betz #1150** polyelectrolyte was added to produce a total concentration of 2 ppm. After 2 minutes the mixing speed was reduced to 20 rpm for 2 minutes and turned off. The mixture was allowed to settle for 30 minutes and vacuum filtered ($0.45\,\mu$ membrane filter) into a clean (phosphate free) 2 liter side-arm flask. This was transferred to a Cubitainer$^{(R)}$, identified, and processed according to the flow diagram in Figure 3.

Wastewater Samples -

These were treated in the same was as water samples per se except that 100 ppm of alum and 2 ppm of Betz #1150 polyelectrolyte were used instead of the values cited above.

(B) Capillary Membrane Dialysis

A Dow+ Miniplant Dialyzer$^{(R)}$ equipped with cellulose capillary membranes was used in this part of the study (Figure 5). The unit as such has a nominal surface area of 15×10^3 cm^2 and a molecular weight cutoff of $\sim 5{,}000$ (manufacturer's specifications).

This was mounted in a universal clamp attached to a ring stand adjacent to ancillary equipment (Figure 7). Gum rubber tubing of convenient lengths was attached to the dialysis chamber at connectors A, B, C and D in Figure 5. "A" represents the influent to the capillary membranes and "B" their effluent. "C" is the influent to the jacket and "D" the effluent. Relationship between the membranes and the jacket per se can be more readily visualized by the compartmentalized diagram in Figure 6. The arrow on the side of the chamber (Figures 5 and 6) represents the direction of flow in the fibers. Those in the jacket (Figure 6) depicts the counterflow of the dialysis medium from "C" to "D".

Tubing attached to the membrane and jacket influent lines are fed through a two-channel finger pump (P) (Zero Max Model 14‡) and terminate

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* Phipps-Bird, Inc., Richmond, Virginia

** Betz Laboratories, Trevose, Pennsylvania

+ Dow Chemical Company, Midland, Michigan.

‡ The Zero Max Company, Minneapolis, Minnesota

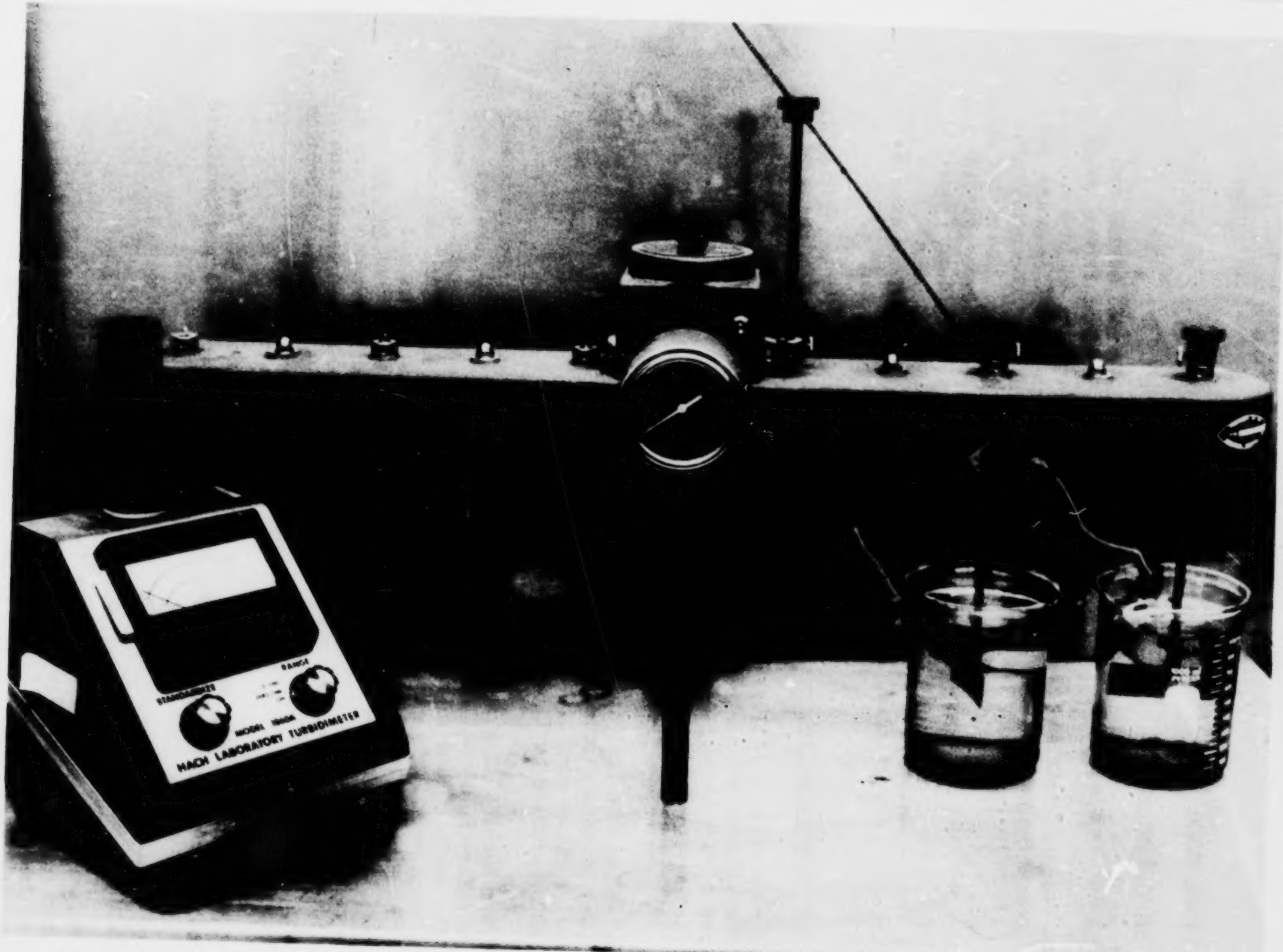
STANDARDIZE
RANGE
HACH LABORATORY TURBIDIMETER

Figure 4. Variable speed mixer assembly employed in standardized coagulation of water and wastewater with alum (aluminum potassium sulfate) and polyelectrolyte (Betz #1150).

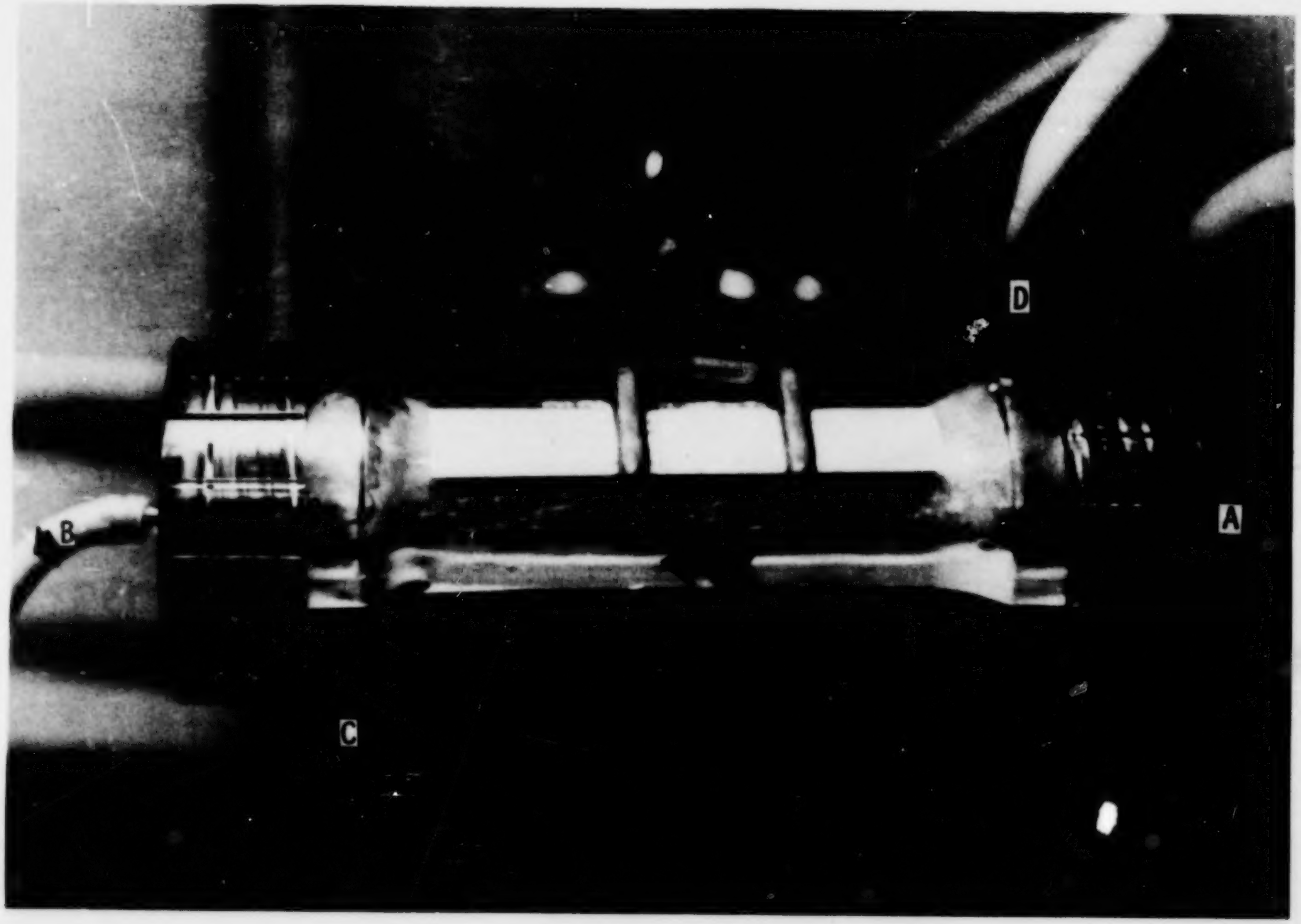

Figure 5. Capillary membrane dialysis assembly: A) Membrane influent (arrow indicate direction of flow); B) Membrane effluent; C) Dialysis medium influent; D) Dialysis medium effluent.

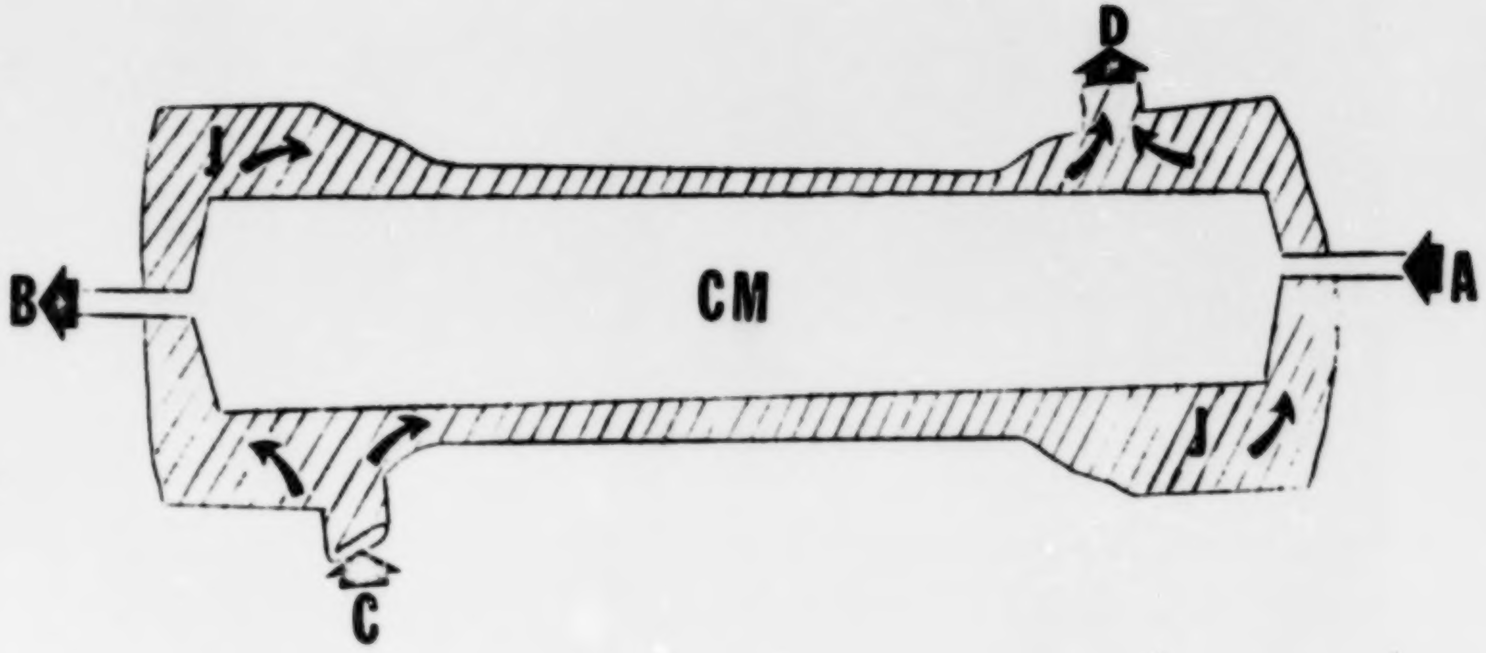

Figure 6. Cross section of capillary membrane dialyzer showing relative positions of membranes to jacket with flowing dialysis medium: A) Membrane influent (arrow indicates direction of flow); B) Membrane effluent; C) Dialysis medium influent; D) Dialysis medium effluent; J) Jacket containing dialysis medium (arrow indicates direction of counter flow).

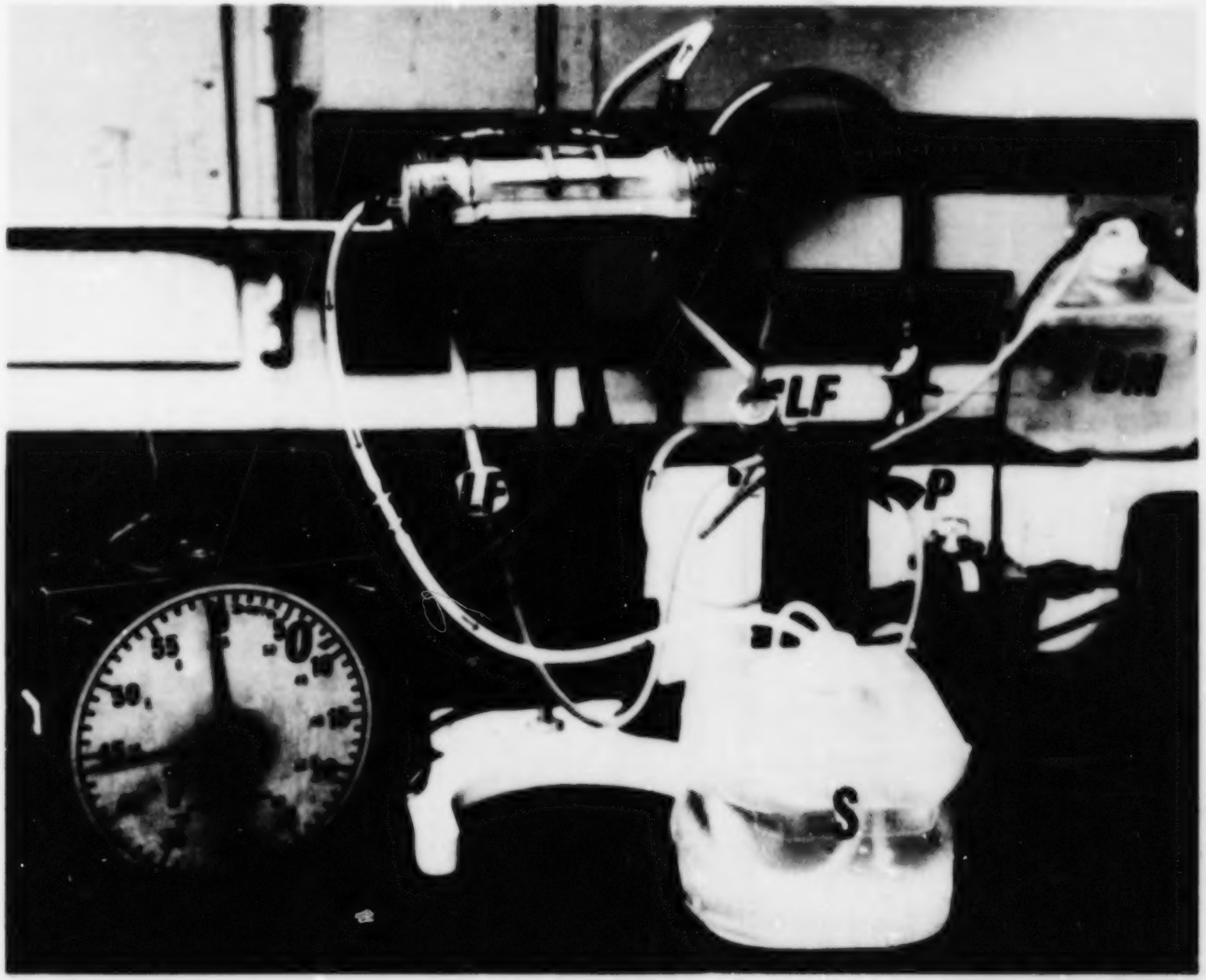

Figure 7. Capillary membrane dialyzer and ancillary equipment: CMD) Capillary membrane dialyzer, A) Membrane influent; B) Membrane influent; C) Dialysis medium influent to jacket; D) Dialysis medium effluent from jacket; LF) Line filters; S) Sample reservoir: DM) Dialysis medium reservoir; P) Pump; T) Timer; O) Timer over ride switch

in the sample and dialysis medium (DM) reservoirs, respectively (Figure 7). Polypropylene nipples are attached to the ends of the tubing to insure positioning on the bottom of each of the containers.

Influent lines were originally equipped with 25mm (0.45 μ) filters (Figure 7-LF) to protect the membranes and jacket from particulates; but can be eliminated as long as samples are pre-filtered and the dialysis medium is limited to freshly collected deionized water.

The effluent line from the membranes (Figure 7-B) also terminates in the sample reservoir whereas the jacket effluent (D) is discharged directly into the laboratory waste treatment system.

A universal timer* is employed to control the dialysis period by turning the pump off following a pre-determined period of operation. It is equipped with a manual override switch (Figure 7-O) which facilitates priming, or can be used for shutting down the system if an emergency arises.

Pre-Dialysis Procedures

Flushing of Preservative from System - Since the capillary membranes are composed of cellulose acetate, they are vulnerable to attack by cellulose degrading microorganisms. For this reason it is necessary to flush the membranes and jacket between each use cycle with 2.5% formaldehyde. As a pre-dialysis requirement, this must be removed by purging the entire system with deionized water.

The dialyzer is set-up as diagramed in Figure 8 with the influent lines for the membranes (A) and jacket (C) feeding from a Cubitainer$^{(R)}$ containing freshly collected deionized water (DW). Effluent lines B and D discharged directly into the laboratory waste treatment system. Approximately 4 liters are pumped through each compartment at a flow rate of approximately 60 ml/minute.

Purging of System with Sample - The membrane influent line (A) is removed with the dionized water (DW) reservoir while continuing to pump until the membranes are displaced with air and effluent is no longer discharged from line (B).

At this point, the influent pick-up (line A) is placed into a Cubitainer$^{(R)}$ containing 1.5 liters of sample (Figure 9-S), and the membranes purged until bubbles are no longer observed to be discharged.

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* Dimco-Gray Company, Dayton, Ohio

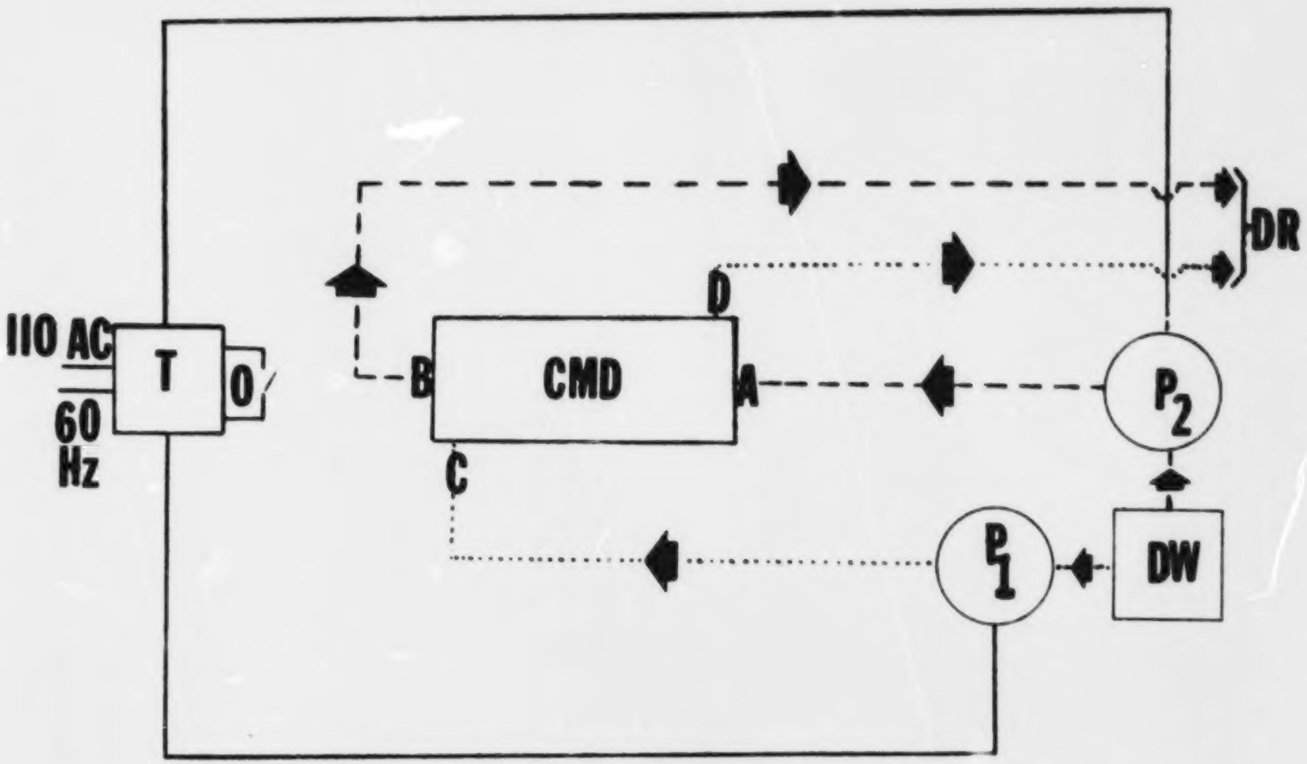

Figure 8. Capillary Membrane Dialyzer: Pre-dialysis purging of system to remove preservative: CMD) Capillary membrane dialyzer; A) Membrane influent; B) Membrane effluent; C) Dialysis medium influent to jacket; D) Dialysis medium effluent from jacket; DW) Deionized water (dialysis medium) reservoir; P_1) Pump channel for dialyzer jacket; P_2) Pump channel for capillary membranes; T) Timer; O) Timer over ride switch; D) Drain to laboratory waste collection system; ---------- Capillary membrane circuit; .... Jacket circuit; ________ Timer control circuit.

Pumping is continued until the first 100 ml is collected in a graduated cylinder and discarded. The pump is turned off at the override switch (O) and the membrane effluent line (B) is inserted into the sample container (Figure 9-S). Thus, a closed circuit is established in which the sample is recirculated through the membranes during the test period.

Sample Dialysis - The dialysis medium (deionized water) reservoir is filled and the timer is set to operate for 45 minutes in the automatic mode. Dialysis medium effluent is continuously discarded as indicated in Figure 9. Flow rates in both channels were maintained at 60 ml/minute in all experiments.

At the conclusion of the dialysis period the sample pick-up is removed from the reservoir and the pump is operated until the effluent line (B) is no longer discharging. The sample container is now sealed, appropriately labeled, and transferred to the analytical laboratory for post-treatment analysis (Figure 3).

Prior to processing the next sample the membranes are eluted with two liters of deionized water while maintaining flow in the jacket. This is followed, as described above, with the pre-dialysis step of purging.

(C) Alumina Adsorption Column

A column was prepared from commercially available interchangeable components (Table 5). This consisted of a 50 x 1200mm Pyrex(R) chromatographic column threaded at both ends and connected with gasketed nylon couplings to an addition funnel and Teflon(R) stopcocked bottom drip to prevent packing material from being discharged with the column effluent.

The assembled column was supported with four universal clamps projecting from a frame of vertical rods which was securely fastened to two parallel pipes running along the back wall of the laboratory (Figure 10). Two additional rods were attached to the bottom of the frame and were adjusted to protect the bottom drip from accidental blows when the column was not in use.

A Big-Jack(R)* was positioned beneath the bottom drip as a means of conveniently adjusting the height of various sized receiving vessels.

Aluminum Column Charging

Alumina** (aluminum oxide), grade F-1 (Lot 2139), 28-48 mesh, was re-screened to obtain a product ranging from 30-60 mesh. This was

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* Precision Scientific Company, Division of GCA Corporation.
** Alcoa, Bauxite, Arkansas

Table 5

*Alumina Column Components and Specifications

COMPONENT	SPECIFICATION	NO. REQUIRED	CATALOG NO.
Addition Funnel	Pyrex$^{(R)}$ 4 Liter Capacity (50 mm Threaded End)	1	5822 - Code 20
Chromatographic Column	Pyrex$^{(R)}$ 50 x 1200 mm	1	5820 - Code 56
Couplings, Nylon	50 mm	2	5840 - Code 20
Adapter-Bottom Drip	Pyrex$^{(R)}$ 50 mm with 1:5 Teflon Stopcock	1	5835-B - Code 20
Filter Disc, Type B	Polyethylene, 50 mm	1	5847 - Code 20
Float	Polyethylene, 50 mm	1	5849 - Code 20

* Ace Glass Company, Vineland, New Jersey 08360

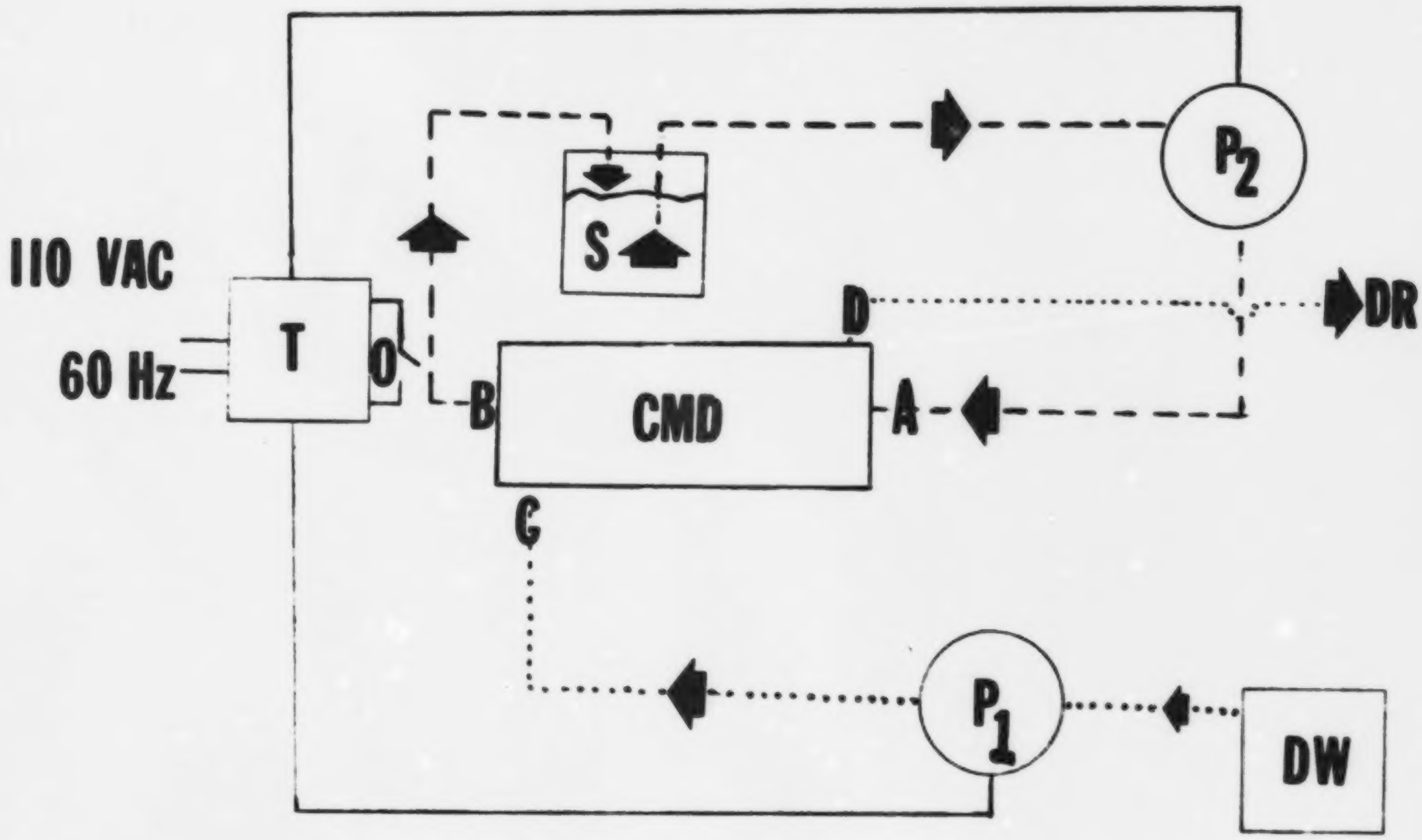

Figure 9. Capillary Membrane Dialyzer: Operational Mode: CMD) Capillary Membrane dialyzer; A) Membrane influent; B) Membrane effluent; C) Dialysis medium influent to jacket; D) Dialysis medium effluent from jacket; DW) Deionized water (dialysis medium) reservoir; P_1) Pump channel for dialyzer jacket; P_2) Pump channel for capillary membranes; S) Sample reservoir; DR) Drain to laboratory waste collection system; T) Timer; O) Timer over ride switch; ---------- Capillary membrane circuit; .... Jacket circuit; ___________ Timer control circuit.

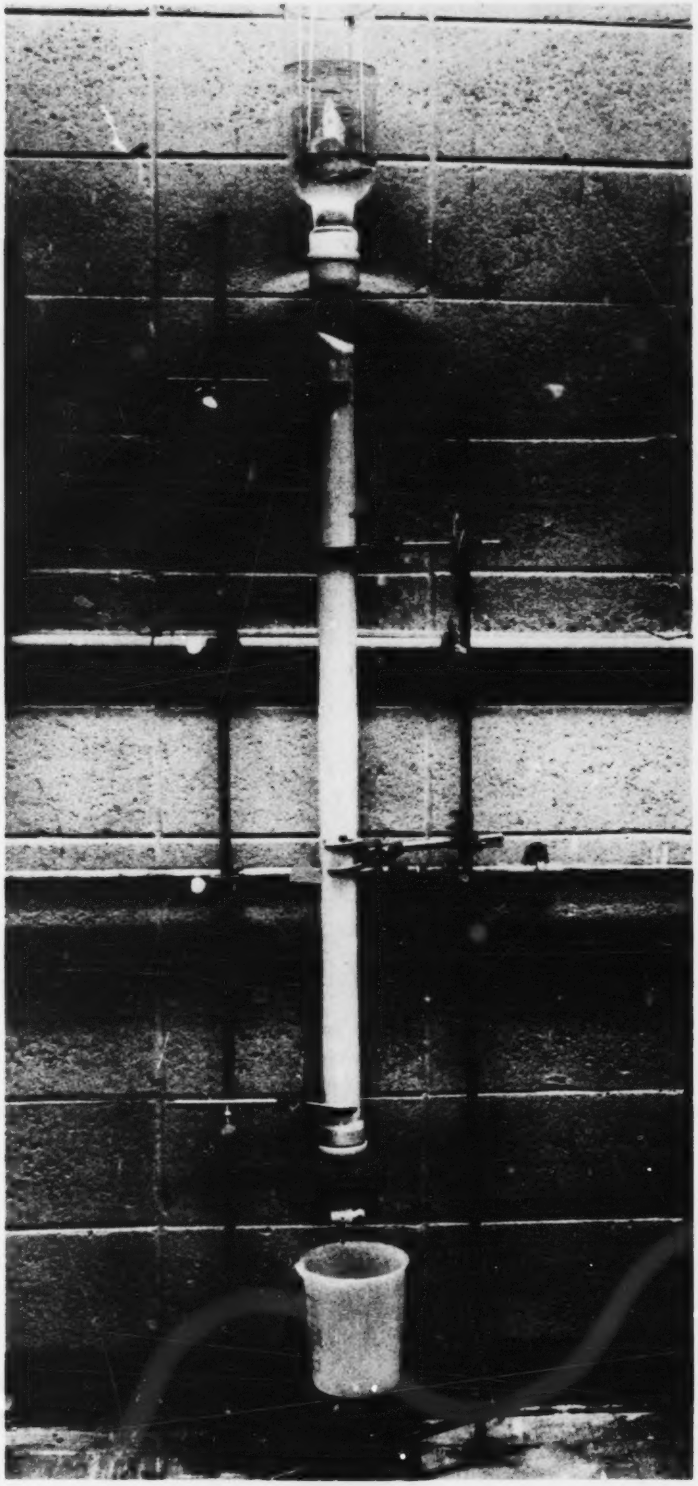

Figure 10. Alumina column suitable for batch treatment of 0.45μ water and wastewater samples.

Table 6

Summary of Analytical Methods

NUTRIENTS

Carbon, organic (dissolved)	SM[2]	Combustion/IR	p. 257
Carbon, organic (total)	SM[2]	Combustion/IR	p. 257
Nitrogen, ammonia	EPA[1]	Distillation, Procedure	p. 134
Nitrogen, total	EPA[1]	Kjeldahl	p. 149
Phosphorus, total	EPA[1]	Persulfate Digestion	p. 263
Phosphorus, dissolved	EPA[1]	Persulfate Digestion	p. 263
Phosphate, ortho	EPA[1]	Direct Colorimetric	p. 263
Phosphate, ortho (dissolved)	EPA[1]	Direct Colorimetric	p. 263
Phosphorus, hydrolyzable	EPA[1]	Sulfuric Acid Hydrolysis	p. 263
Phosphorus, hydrolyzable (dissolved)	EPA[1]	Sulfuric Acid Hydrolysis	p. 263

CATIONS

Calcium (Ca)	EPA[1]	Atomic Absorption	p. 102
Potassium (K)	EPA[1]	Atomic Absorption	p. 115
Magnesium (Mg)	EPA[1]	Atomic Absorption	p. 112
Sodium (Na)	EPA[1]	Atomic Absorption	p. 118
Copper (Cu)	EPA[1]	Atomic Absorption	p. 106
Zinc (Zn)	EPA[1]	Atomic Absorption	p. 120
Iron (Fe)	EPA[1]	Atomic Absorption	p. 108
Manganese (Mn)	EPA[1]	Atomic Absorption	p. 114
Cobalt (Co)	PE[3]	Atomic Absorption	
Boron (B)	SM[2]	Curcumin or Carmine	p. 69
Silicon (Si)	EPA[1]	Silicomolybdate Color	p. 273

ANIONS

Sulfate (SO_4)	EPA[1]	Turbidimetric	p. 286
Sulfite (SO_3)	SM[2]	Iodide-Iodine	p. 337
Nitrate (NO_3)	EPA[1]	Brucine Sulfate	p. 170
Nitrite (NO_2)	EPA[1]	Diazotization	p. 195
Chloride (Cl^-)	EPA[1]	Mercuric Nitrate	p. 29

MISCELLANEOUS ANALYSES

pH	EPA[1]	Electrometric	p. 230
Conductivity	SM[2]	Wheatstone Bridge	p. 323
Total Dissolved Solids	EPA[1]	Gravimetric, 180°C	p. 275
Total Solids	EPA[1]	Gravimetric, 105°C	p. 280
Hardness (Carbonate/Bicarbonate)	EPA[1]	EDTA Titration	p. 76
Total Alkalinity	EPA[1]	Electrometric	p. 6

EPA[1] "Methods for Chemical Analysis of Water and Wastes", Environmental Protection Agency, Water Quality Office. Analytical Quality Control Laboratory, Cincinnati, Ohio, (1971).

SM[2] "Standard Methods for the Examination of Water and Wastewater", APHA, AWWA, WPCF, ed. 13, American Public Health Association, New York, New York, (1971).

PE[3] "Analytical Methods for Atomic Absorption Spectrophotometry", Perkin Elmer Corporation, Norwalk, Connecticut, (1968).

slurred a minimum of 3X in deionized water and decanted to remove fines. The product was dried to constant weight at 100°C. Approximately 1800 grams was added to the column through the addition funnel with gentle agitation, immediately wetted by drop wise addition of deionized water (stopcock closed) until completely covered, and gradually drained with continued addition of water. This allowed the individual alumina particles to uniformly pack while minimizing problems of channeling.

The alumina, although previously unused, was treated with calcium hydroxide ($Ca(OH)_2$) and sodium hydroxide (NaOH) by conventional techniques to remove any phosphorus which may have been present[7]. Following this procedure the column was washed with 5 volumes of deionized water and retained in the alkaline form throughout the study.

Approximately 1.6 liters of water was required to completely cover the alumina in the column. Upon draining a total of 765 ml could be collected while leaving 835 ml physically in contact with the alumina surface. This could be displaced by dilution following further addition of water and drainage. As such this provided the rationale for the treatment of individual samples.

Alumina Treatment of Samples

The following procedure was employed to treat individual filtered samples:

(1) Completely drain column.
(2) Add 3 liters of deionized water.
(3) Drain 500 ml to displace possible entrapped air bubbles.
(4) Allow to stand 45 minutes and completely drain.
(5) Add 3 liters of sample to column; repeat step 4 and discard.
(6) Add 2 liters of sample to column, drain, collect, identify and analyze.
(7) Add 3 liters of deionized water to column; allow to stand until ready for processing of next sample.

It was considered that potential contamination of consecutive samples was an inherent problem associated with this method of treatment; but could in part be overcome by adapting a standardized procedure.

Analytical Methodology

Replicate analysis of unfiltered and filtered samples for each parameter was conducted according to current U.S. Environmental Protection Agency[8] or Standard Methods[9] Procedures unless otherwise specified (Table 6).

Standards

Standards for nutrients as outlined in Table 7 were prepared on the day of use by dissolving appropriate quantities of reagent grade chemicals in pretested distilled water to provide 1000 ppm stock solutions. Aliquots were subsequently diluted to prepare 3-4 concentrations of working standards in volumetric flasks. Standard curves were constructed with replicate analysis at each concentration to insure reproducibility. Further analysis of standards was conducted periodically during a given test period, i.e., one working day, as both a check on precision and to correct instrument drift.

Nutrients

In the case of low level phosphorus and nitrogen (Kjeldahl, ammonia, nitrate/nitrite) analysis, standards were tested on a more frequent basis to confirm stability and validity of test data. It should be pointed out that delays must be minimized between the time a sample is collected and analysis for nutrients is initiated if preservatives are to be eliminated. As previously discussed, this is highly desirable in the case of phosphorus analysis where preservatives are suspected of interfering with the colorimetric reactions. An alternate procedure would involve freezing filtered and unfiltered samples, but should only be considered if analytical services are not readily available.

Cations

All samples analyzed for specific cations by atomic absorption spectrophotometry[8,9,10] were preserved with nitric acid. Sulfuric acid was employed for those to be tested for silica and boron. Working standards for metal cations were conveniently prepared from 1000 ppm commercially available stock solutions (Table 7).

Anions

Anions given priority for analysis included nitrate and nitrite which were also processed without benefit of preservatives. Refrigerated samples (filtered and unfiltered) were analyzed for sulfate and chloride within a week following collection. Those intended for analyses of sulfite content were cooled to 4°C. in the field and analyzed the same day. Although originally specified as an analytical parameter for this program sulfide was eliminated due to the large number of variables influencing its analysis[9].

Miscellaneous Analysis

Of the miscellaneous analyses pH and conductivity were determined immediately before and after filtration; alkalinity and solids (total and dissolved), were set up from refrigerated samples within 24 hours of collection. Standards and their derivation are summarized in Table 7.

Table 7

Summary of Analytical Standards

NO.	NUTRIENTS	STANDARD	SOURCE/CATALOG NUMBER	METHOD OF PREPARATION	STORAGE TEMPERATURE °C	FREQUENCY OF PREPARATION
1	Carbon, total	See #2 and #3	-	-	-	-
2	Carbon, organic	Potassium Hydrogen Phthalate	Fisher Scientific Co. P-243	Weigh, Dissolve, Dilute Distilled Water	-	Daily
3	Carbon, inorganic	Sodium Carbonate Sodium Bicarbonate	" S-263 " S-233	"	-	"
4	Nitrogen, ammonia	Ammonium Chloride	" A-661	"	-	"
5	Nitrogen, total	Ammonium Chloride	" A-661	"	-	"
6	Nitrogen, nitrite/ nitrate	Sodium Nitrite, Potassium Nitrate	" S-347 " S-383	"	-	"
7	Phosphorus, Hydrolyzable	Mono Basic Potassium Phosphate	" P-382	"	-	"
8	Phosphorus, total	Mono Basic Potassium Phosphate	" P-382	"	-	"
9	Phosphate, ortho	Mono Basic Potassium Phosphate	" P-382	"	-	"
	CATIONS					
1	Calcium (Ca)	Calcium Carbonate/Dilute Nitric Acid	Fisher Scientific Co. So-C-191	Decimal Dilutions/Distilled Water	Store Stock Sol'n Only/4°C	Working Stds./Daily
2	Potassium (K)	Potassium Chloride/Distilled Water	" So-P-351	"		"
3	Magnesium (Mg)	Magnesium Metal/Dilute Nitric Acid	" So-M-51	"	"	"
4	Sodium (Na)	Sodium Bicarbonate/Dilute Nitric Acid	" So-S-139	"	"	"
5	Copper (Cu)	Copper Oxide/Dilute Nitric Acid	" So-C-194	"	"	"
6	Zinc (Zn)	Zinc Oxide/Dilute Nitric Acid	" So-Z-13	"	"	"
7	Manganese (Mn)	Manganese Metal/Dilute Nitric Acid	" So-M-81	"	"	"
8	Cobalt (Co)	Cobalt Metal/Dilute Nitric Acid	" So-C-193	"	"	"
9	Iron (Fe)	Ferric Chloride/Distilled Water	" So-I-124	"	"	"
10	Boron (B)	Boric Acid/Distilled Water	" So-B-155	"	"	"
11	Silicon (Si)	Sodium Silicate/Distilled Water	" So-S-465	"	"	"
	ANIONS					
1	Sulfate (SO_4)	Sulfuric Acid	Fisher Scientific Co. So-A-200	Decimal Dilutions/Distilled Water	Store Stock Sol'n Only/4°C	Working Stds./Daily
2	Sulfite (SO_3)		"			
3	Nitrate (NO_3)	See Nutrients #6	-	-	-	-
4	Nitrite (NO_2)	See Nutrients #6	-	-	-	-
5	Chloride (Cl)	Sodium Chloride	Fisher Scientific Co. S-271	Weigh/Dissolve/Dilute	-	Working Stds./Daily
	MISCELLANEOUS					
1	Conductivity	Sodium Chloride	Fisher Scientific Co. S-271	Weigh, Dissolve/Dilute Dis. Water	4°C	Weekly
2	Total Diss. Solids		-	-	-	-
3	Total Solids		-	-	-	-
4	Total Alkalinity			Weigh, Dissolve/Dilute Dis. Water	-	Daily
5	Hardness (Carbonate/Bicarbonate)	Calcium Carbonate	Fisher Scientific Co. C-65	"	-	"
6	pH	pH 4.0 Buffer Concentrate pH 7.0 Buffer Concentrate pH 10.0 Buffer Concentrate	" So-B-99 " So-B-109 " So-B-141	Dilute Distilled Water " "	Concentrated 4°C " "	Weekly " "

SECTION VI

DISCUSSION

Raw data as reported for all samples have been conveniently transposed into five tables (Appendix 1A-1E) representing each of the water (Valley Creek, French Creek, Trout Run) and wastewater effluent (Phoenixville and Hatfield) collection sites to compare analytical data before (unfiltered and filtered) and after treatment (alumina absorption, capillary membrane dialysis, coagulation).

Data representing individual parameters have been plotted as composite curves (Figures 11-33) to graphically depict comparative treatment effectiveness for samples collected from the same source at different times or stream water and treatment plant effluents collected within the same time span. Each graph has been prepared by plotting values for untreated samples (unfiltered designated as "U"; filtered as "F") and following treatment by alumina adsorption ("A"); capillary membrane dialysis ("D"); and coagulation ("C").

Although not amendable to statistical analysis as a result of the limited sampling, this provides an interesting insight into the relative merits and efficiency of each method of treatment. The range of percentage reduction ΔR) for each parameter is summarized in Table 8 and is derived from the ΔR's reported in Appendix 1A to 1E. These were determined by utilizing data for filtered/untreated samples as baseline values and calculating the percentage reduction for each method of treatment. In some cases it will be seen that no changes have been detected following treatment (as indicated by "0" in Table 8), or in others where as increase (+) has occurred above the untreated control value. In most cases this occurs either because a specific treatment process contributes ions to treated waters e.g., excess of sulfate observed in water and wastewater treated with alum (aluminum potassium sulfate) or a lack in sensitivity of certain analytical methods for detecting a change at relatively low concentrations.

TOTAL CARBON

Alumina absorption and dialysis demonstrated equivalent efficiency in reducing the total carbon content of water and wastewater. Maximum efficiency determined for all treated waters was 86% and 81%, respectively. In constrast, treatment with polyelectrolyte (Betz #1150) and alum (aluminum potassium sulfate) failed to reduce total carbon by more than 13%. Total carbon removal, as seen by inspection of Figures 11-17, can primarily be attributed to the inorganic fraction.

INORGANIC CARBON

Dialysis and alumina adsorption produce comparable results in removal

Table 8

Summary of Water & Wastewater Effluent Treated by Alumina Adsorption; Capillary Membrane Dialysis; And Coagulation with Alum/Polyelectrolyte

Range % Δ R*

		STREAM WATER									WASTEWATER EFFLUENT					
		FRENCH CREEK			TROUT RUN			VALLEY CREEK			PHOENIXVILLE			HATFIELD		
NO.	PARAMETER	Alumina	Dialysis	Coagulation	Alumina	Dialysis	Coagulation	Alumina	Dialysis	Coagulation	Alumina	Dialysis	Coagulation	Alumina	Dialysis	Coagulation
1	Total Carbon	+ - 40**	33-50	9-13	55-63	41-73	7-13	51-86	63-81	+ - 6	72-81	50-78	9-22	70-74	63-73	3-7
2	Organic Carbon	+ - 50	+ - 17	4-7	+ - 55	+ - 77	20-44	0-91	+ - 75	+ - 0	13-57	+ - 80	0-36	0-40	+ - 35	+ - 20
3	Inorganic Carbon	25-30	62-70	14-25	45-79	67-71	0-8	53-86	63-84	0-20	89-98	76-81	34-50	41-90	50-60	5-13
4	Total Phosphate P	85-96	+ - 75	71-96	50-70	+ - 60	+ - 0	33-75	+ - 86	0-75	>99	50-62	62-85	83-96	24-56	50-96
5	Hydrolyzable Phos. P	75-92	+ - 90	75-90	0	+ - 70	+ - 0	50-90	+ - 86	0-90	>99	50-62	62-63	75-98	35-62	65-75
6	Phosphate - Ortho	66-90	+ - 60	60-90	0-80	+ - 60	+ - 80	75-93	+ - 86	0-80	>99	0-86	66-96	96-98	40-60	80-96
7	Kjeldahl E Nitrogen	+	0-75	+ - 0	+ - 25	0-50	+ - 66	+ - 0	0-66	+ - 33	92-97	84-90	+ - 40	+ - 82	+ - 7	+ - 12
8	Ammonia Nitrogen	+	+ - 70	+ - 0	+ - 50	0-50	0-50	+ - 0	0-80	+	>98	71-94	0-38	+ - 89	+ - 82	+ - 90
9	Nitrate Nitrogen	+ - 37	86-96	0-23	+ - 83	77-2	+ - 45	0-39	84-99	4-9	0-50	0-70	+ - 80	0-6	60-93	0-6
10	Nitrite Nitrogen	+ - 60	0-80	+ - 60	0	+ - 70	+ - 70	0-50	0-95	0-50	U ***	50-87	+ - 12	0-4	56-90	0-4
1	Ca	95-98	46-80	+ - 5	>99	47-78	3-5	>99	69-85	+ - 4	>99	65-69	12-27	98-99	36-70	1-53
2	Mg	96-98	50-80	+ - 20	98-99	61-81	0-9	95-99	76-84	+ - 4	98-99	66-69	0-16	92-96	33-72	0-4
3	Zn	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
4	K	75-92	28-75	+	85-90	80-85	+	85-90	50-90	+	70-98	76-85	+	+ - 96	50-75	10-19
5	Na	+	67-79	+ - 6	+	8-83	+ - 0	+	80-94	0	21-27	77-80	0-1.7	+ - 3	48-75	1-12
6	B	50-60	50-98	0-50	0-93	66-86	0-60	0-96	70-90	0-50	80-88	58-87	0 + -	72-88	72-90	11-50
7	Si	97-98	75-79	3-27	60-98	74-82	5-60	25-86	69-80	0-23	91-98	72-76	+ - 33-4	96-98	49-73	3-16
8	Co	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
9	Cu	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
10	Fe	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
1	SO_3	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2	SO_4	4-99	11-57	+	23-99	19-50	+	84-97	44-73	+	94-99	54-65	+	86-98	28-62	+ - 0.6
3	Cl	0-12	8-78	+ - 12	+ - 57	72-84	+ - 47	0-26	12-62	0-56	+	81-87	+ - 36	+ - 0	28-88	1-17
1	Specific Conductance	+ - 0	58-67	+ - 6	+ - 30	71-77	5-6	2-64	72-82	+ - 2	48-58	68-75	+	33-62	38-74	+ - 4
2	Hardness-EDTA	96-99	23-81	+ - 27	>99	57-68	+ - 3	>99	70-86	+ - 4	>99	60-67	5-7	97-99	40-64	+ - 5
3	Alkalinity - Total	-	74-75	22-25	+ - 30	71-77	5-6	34-84	74-89	6-8	70-93	73-81	11-22	72-80	62-81	5-53
4	Dissolved Solids	+	55-56	+ - 4.3	+	15-92	+ - 15	19-28	51-80	1-37	21-51	71-74	+ - 50	18-52	34-67	+ - 0.1

* % reduction in treated waters compared to untreated (filtered) control ; ** + - concentration greater than untreated (filtered) control ; *** U - concentration unchanged from untreated (filtered) contro

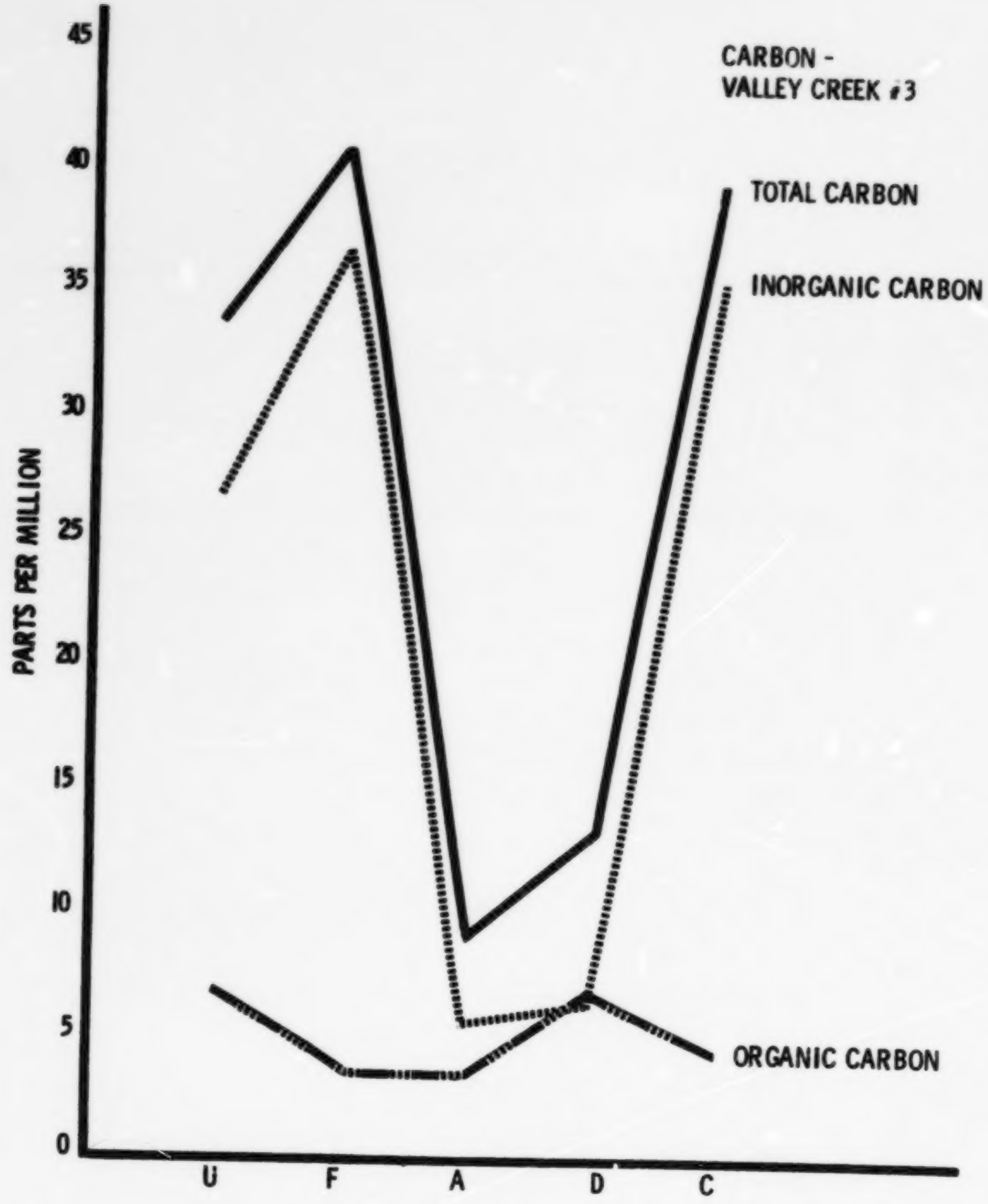

Figure 11. Carbon profile of water collected from Valley Creek (April 1973) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (D) dialyzed; (C) coagulated.

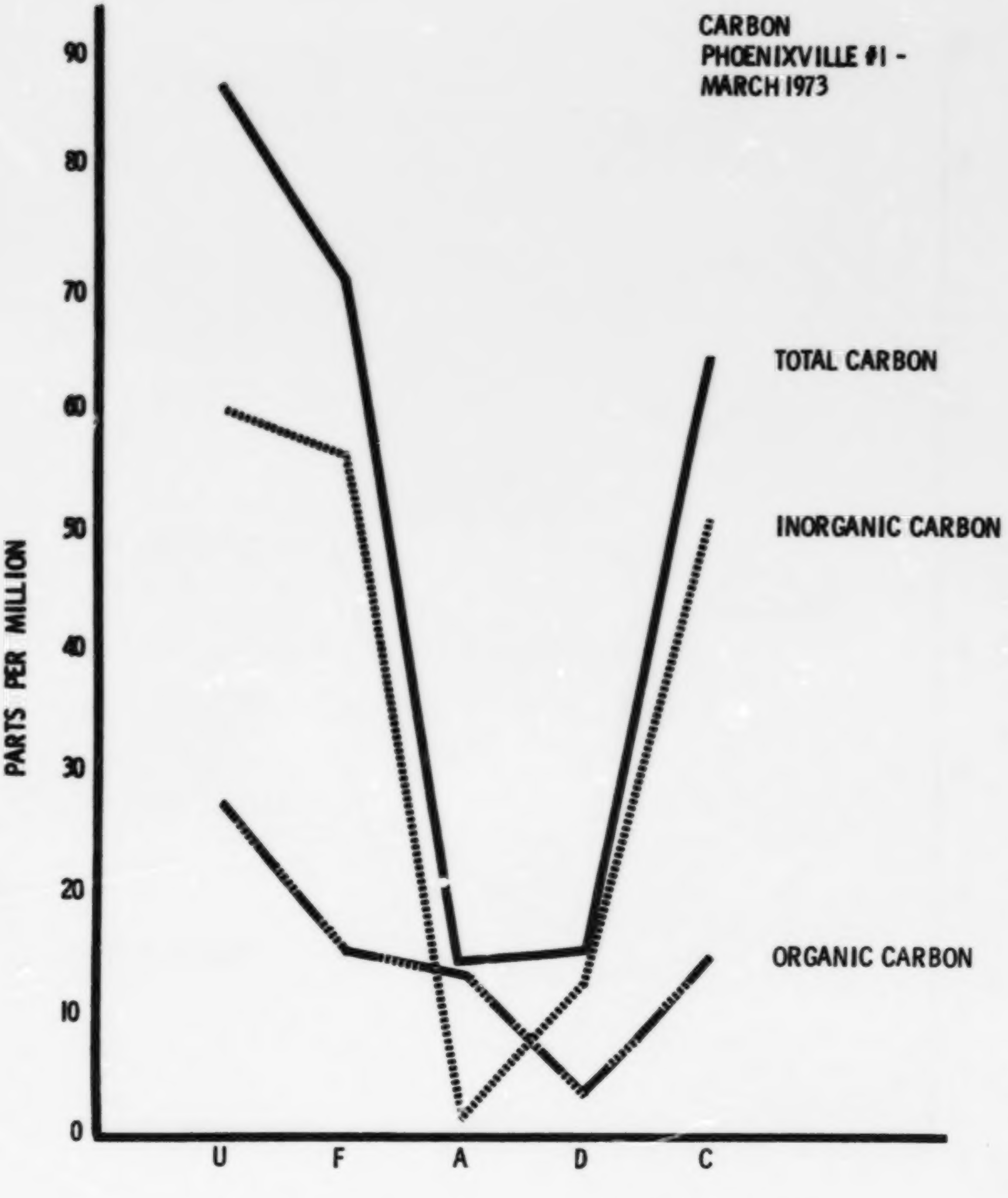

Figure 12. Carbon profile of Phoenixville secondary wastewater effluent (collected March 1973) before and after processing: (U) Unfiltered; (F) filtered; (A) alumina adsorption; (D) dialyzed; (C) coagulated.

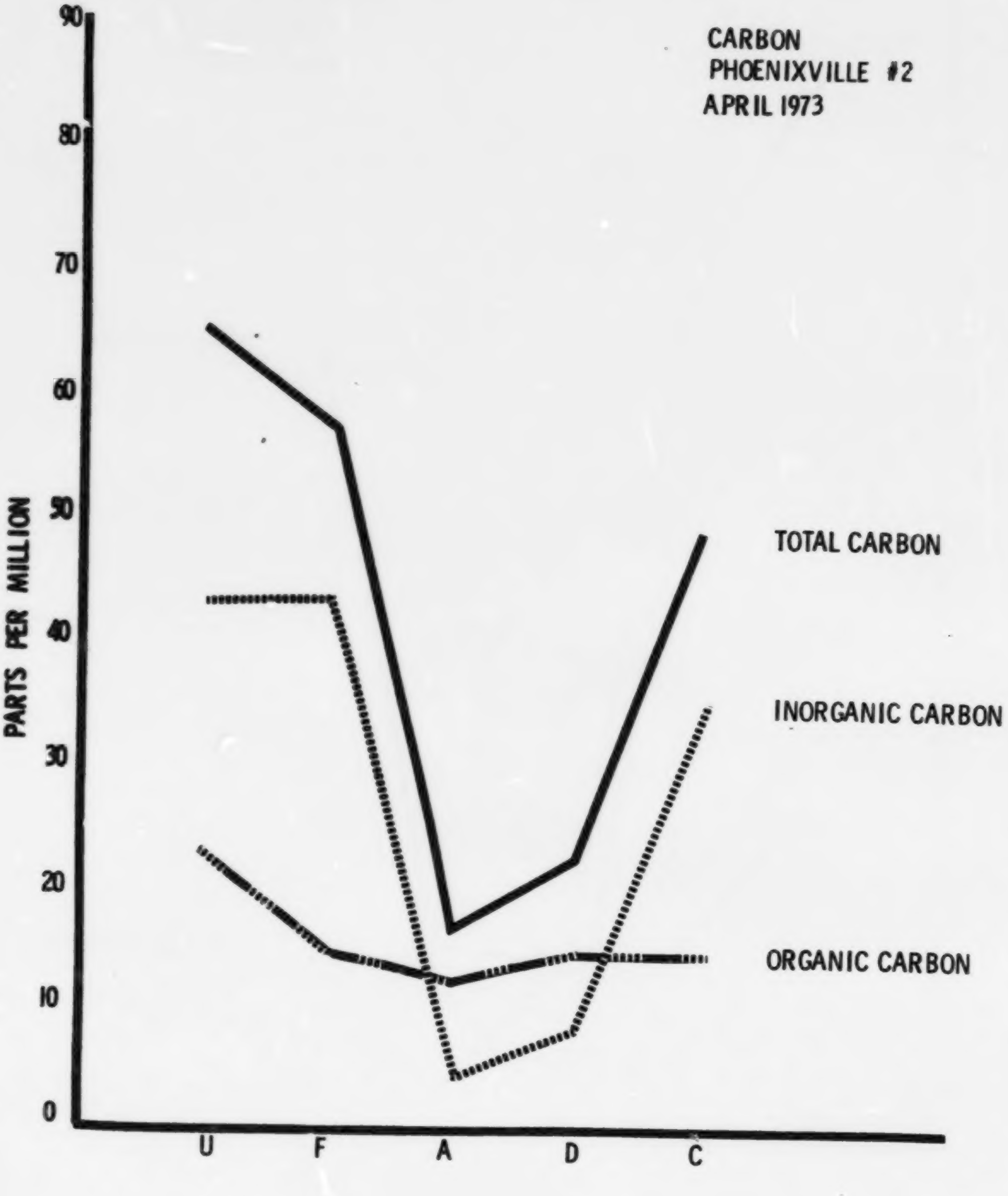

Figure 13. Carbon profile of Phoenixville secondary wastewater effluent (collected April 1973) before and after processing. (U) Unfiltered; (F) filtered; (A) alumina adsorpiton; (D) dialyzed; (C) coagulated.

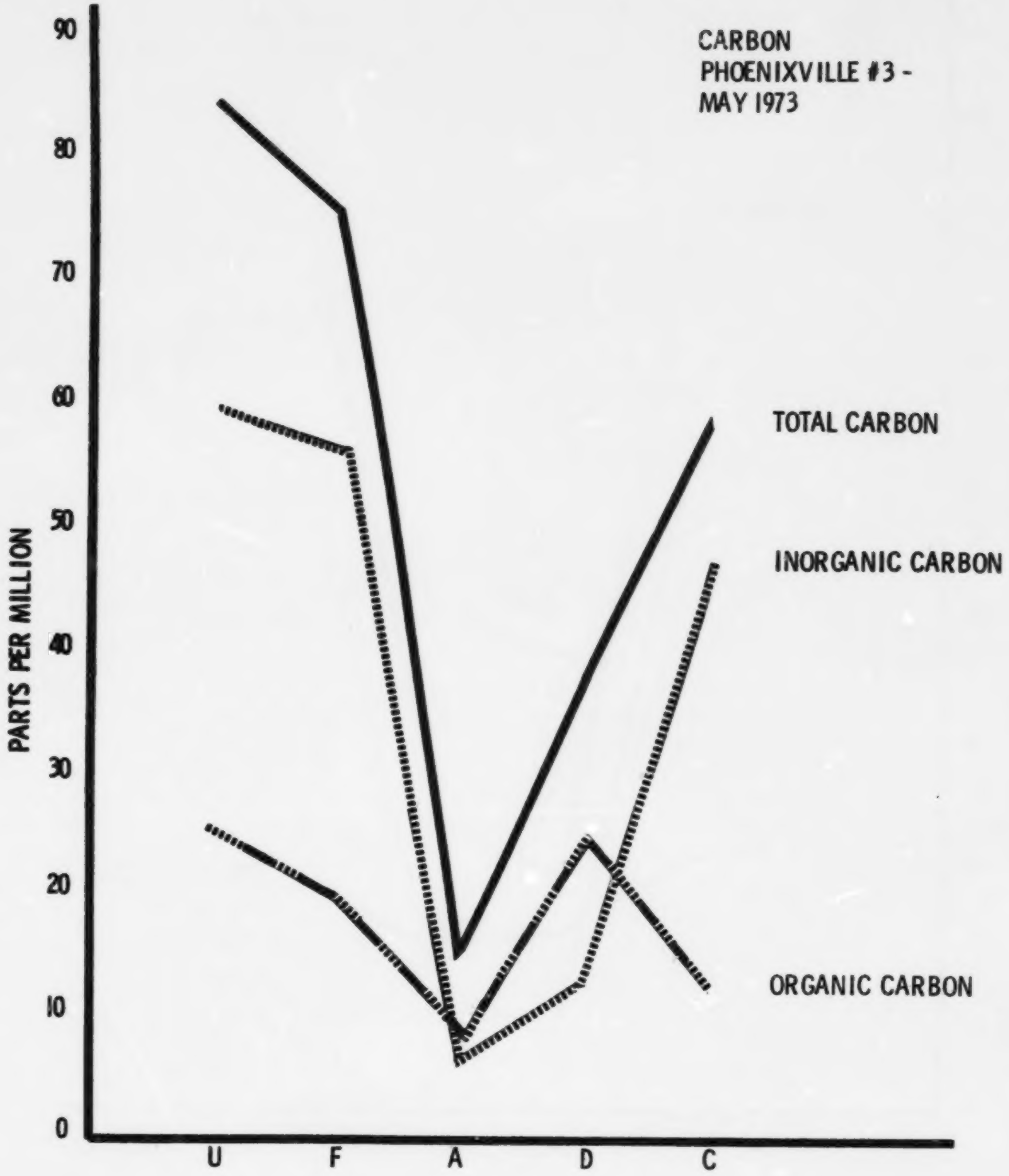

Figure 14. Carbon profile of Phoenixville secondary wastewater effluent (collected May 1973) before and after processing: (U) Unfiltered; (F) filtered; (A) alumina adsorpiton; (D) dialyzed; (C) coagulated.

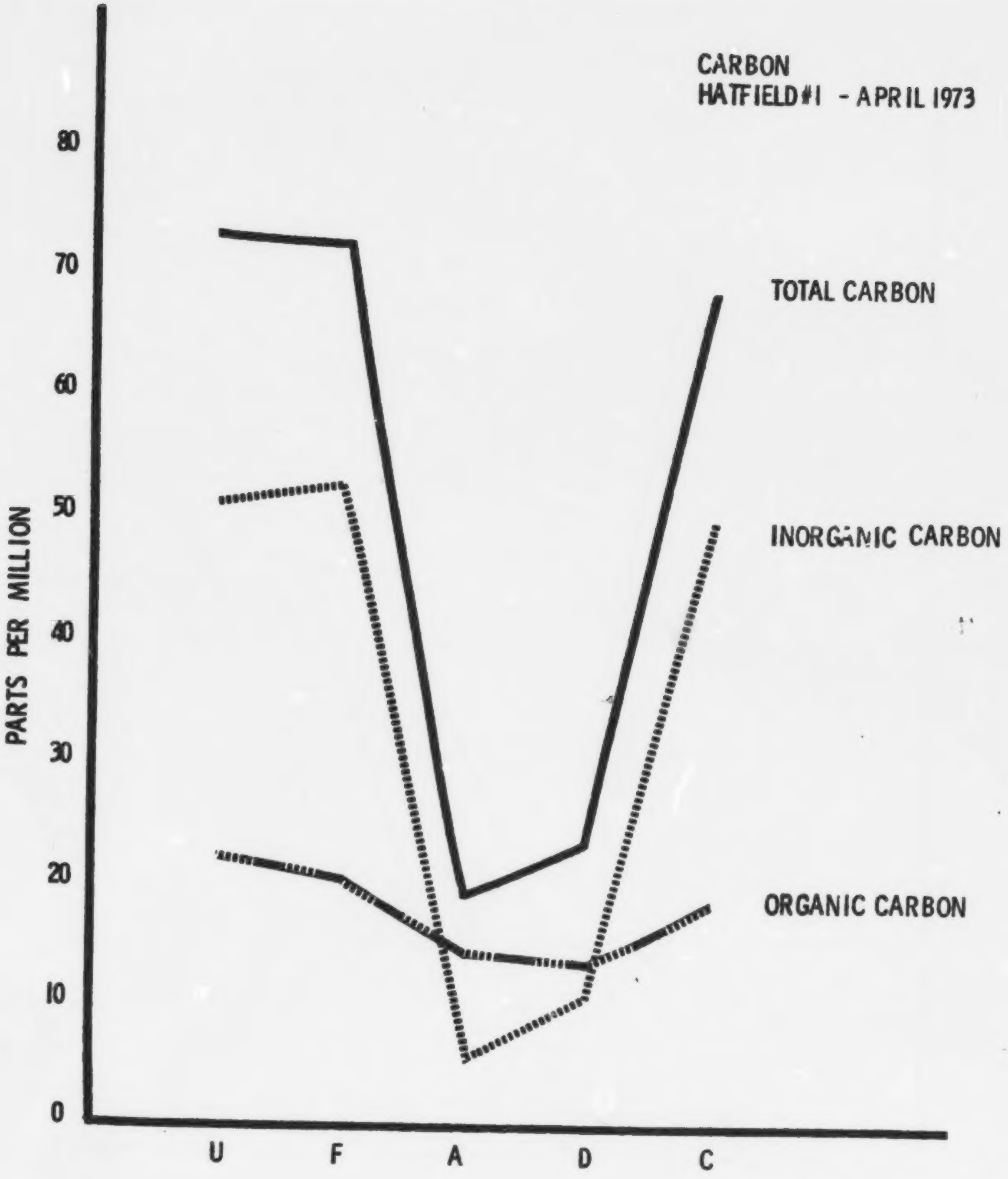

Figure 15. Carbon profile of Hatfield tertiary wastewater effluent (collected April 1973) before and after processing: (U) Unfiltered; (F) filtered; (A) alumina adsorption; (D) dialyzed; (C) coagulated.

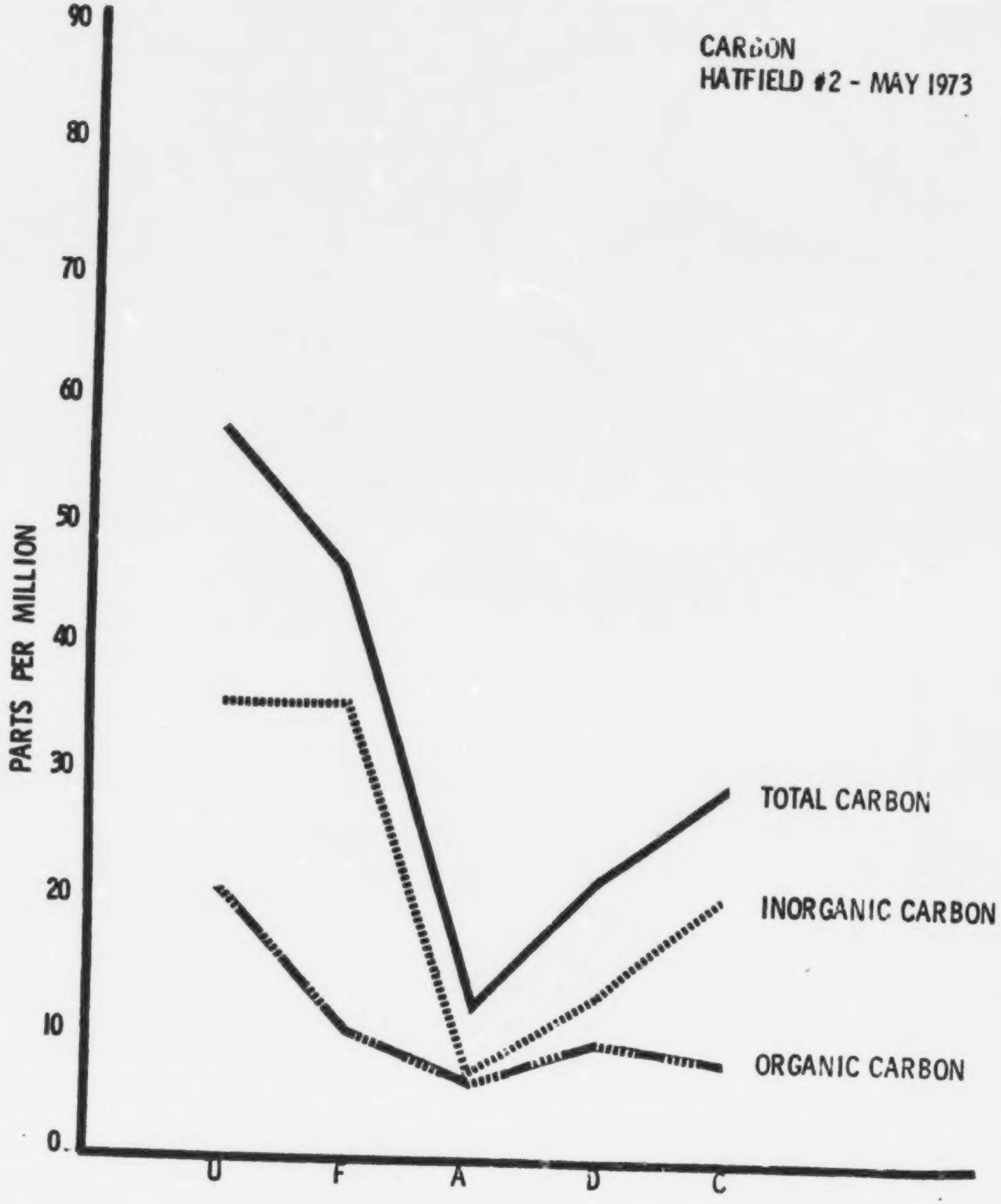

Figure 16. Carbon profile of Hatfield tertiary wastewater effluent (collected May 1973) before and after processing: (U) Unfiltered; (F) Filtered; (A) alumina adsorption; (D) dialyzed; (C) coagulate.

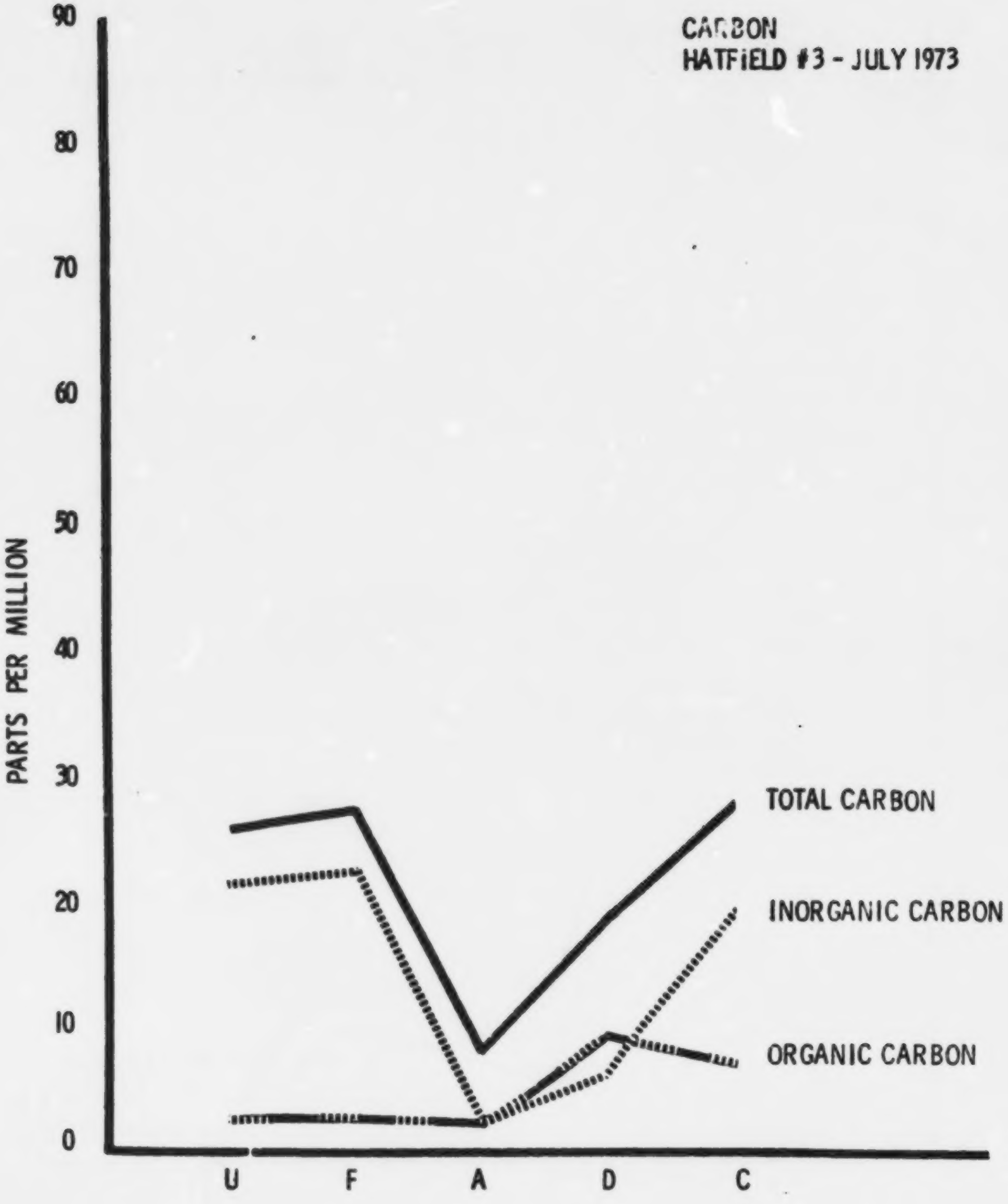

Figure 17. Carbon profile of Hatfield tertiary wastewater effluent (collected July 1973) before and after processing: (U) Unfiltered; (F) Filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

of inorganic carbon from stream water and wastewater effluent, although alumina appears to be slightly superior (Figures 11-17). Based on the similar effectiveness of alumina and dialysis in reducing sodium (Figure 29), calcium (Figure 25), magnesium (Figures 26 and 27), and total alkalinity (Figure 33) levels of treated waters, it is highly suggestive that inorganic carbon is mainly derived from sodium carbonate (Na_2CO_3), sodium bicarbonate ($NaHCO_3$), magnesium carbonate ($MgCO_3$) and calcium carbonate ($CaCO_3$).

Further reduction of the inorganic content by dialysis could be anticipated by extending the dialyzing period from the standard forty-five minutes used in this study to 1.5-3 hours.

Coagulation, of the three methods similarly is the least efficient when it is considered that 100 ppm of alum (aluminum potassium sulfate) was used to treat wastewater samples and 20 ppm for those derived from streams. This may be attributable to the overall differences in physico-chemical characteristics of water from such diverse sources as reflected by variations in total and dissolved solids (Figures 34-38) and specific conductance (Figure 31).

TOTAL ORGANIC CARBON

Removal of total organic carbon (TOC) by alumina, dialysis, and coagulation presents a relatively inconsistent pattern, however, it is concluded that coagulation was the least efficient on a qualitative basis. It is speculated that more of the organic carbon associated with macromolecules could have been removed by dialysis if membranes exhibiting a higher molecular weight cutoff (i.e., ~ 5000) had been used for these studies. In this case, extension of the dialysis period could not be expected to enhance organic carbon removal due to their association with macromolecules which are excluded by the cellulose membrane under consideration.

PHOSPHORUS

Differences in profiles of total phosphate phosphorus, hydrolyzable phosphate phosphorus, and *ortho*-phosphate for all waters before and after treatment are outlined in the Appendix 1A-1E. Raw stream water and wastewater values for all parameters are shown in Table 9.

Treatment efficiencies *per se* are summarized in Table 10 were found to be a function of the initial concentration as outlined in Table 9.

Alumina provides a highly effective method of treatment (99%) for all species of phosphorus in effluent of the Phoenixville (secondary) plant but fell to the 75-98% level for water from the Hatfield facility; 75-96% for French Creek; 50-93% for Valley Creek; and 0-80% for Trout Run.

Table 9

Comparative Concentrations of Phosphorus in Raw Stream Water and Wastewater Effluent Prior to Treatment

	RANGE - PPM		
SOURCE	TOTAL PO_4 P	HYDROLYZABLE PO_4 P	ORTHO PHOSPHATE
French Creek	.03 - 0.6	.04 - .06	.03 - .04
Trout Run	.01 - .02	.01 - .02	.01
Valley Creek	.03 - .16	.03 - .07	.02 - .04
Phoenixville (Secondary)	8	7 - 8	3 - 7
Hatfield (Tertiary)	.21 - .64	.20 - .63	.09 - .53

Table 10

Summary of Phosphorus Treatment Efficiencies for Water & Wastewater

SOURCE	PARAMETER	RANGE OF % REDUCTION FOLLOWING:		
		ALUMINA ADSORPTION	CAPILLARY DIALYSIS	COAGULATION
FRENCH CREEK	Total PO_4 - P	75 - 96	+ - 75	75 - >90
	Hydrolyzable PO_4 - P	75 - 92	+ - 90	75 - 90
	Ortho-Phosphate	80 - 90	+ - 66	60 - 90
VALLEY CREEK	Total PO_4 - P	50 - 75	+ - 66	0 - 75
	Hydrolyzable PO_4 - P	66 - 90	+ - 66	0 - 90
	Ortho-Phosphate	75 - 93	50 - 66	0 - 50
TROUT RUN	Total PO_4 - P	>50 - 70	+ - 60	+ - 0
	Hydrolyzable PO_4 - P	0	+ - 70	+ - 0
	Ortho-Phosphate	0 - 80	+ - 0	70 - 80
HATFIELD	Total PO_4 - P	83 - 98	24 - 58	50 - 62
	Hydrolyzable PO_4 - P	75 - 98	35 - 62	68 - 75
	Ortho-Phosphate	92 - 98	40 - 60	80 - 96
PHOENIXVILLE	Total PO_4 - P	99	50 - 62	62 - 85
	Hydrolyzable PO_4 - P	99	50 - 62	62 - 83
	Ortho-Phosphate	99	0 - 66	66 - 96

+ = Exceeds Control Value; 0 = Unchanged.

Table 11

Summary of Total Phosphate Phosphorus Removed

By 0.45μ Filtration of Stream Water & Wastewater Effluent

SOURCE	SAMPLE NO.	PPM		
		UNFILTERED	FILTERED	REMOVED
FRENCH CREEK	1	0.6	0.05	0.55
	2	0.04	0.04	0
	3	0.03	0.07	+.04
	4	0.05	0.05	0
TROUT RUN	1	0.02	0.01	.01
	2	0.01	0.01	0
	3	0.02	0.02	0
VALLEY CREEK	1	0.05	0.04	.01
	2	0.03	0.03	0
	3	0.16	0.03	.13
	4	0.03	0.02	.01
PHOENIXVILLE	1	8	8	0
	2	8	8	0
	3	8	7	1
HATFIELD	1	0.22	0.12	.08
	2	0.21	0.16	.05
	3	0.64	0.53	.11

By comparison, alum/polyelectrolyte coagulation removed 62-96% of phosphorus from Phoenixville waters; 50-80% from Hatfield; and 60-90% from French Creek. Valley Creek produced more variable results with removal of 0-90% for all samples tested; and Trout Run data ranging from values exceeding controls to as high as 80%.

Of the three methods dialysis provided to be the most unreliable under the test conditions outlined in Section V. With Phoenixville effluent overall phosphorus reduction ranged from 0-66% and Hatfield 24-60%. For raw stream waters containing lower concentrations of phosphorus, dialysis was highly unpredictable with post-treatment values frequently exceeding that of controls (Table 10).

Inspection of Figures 18-21 and Table 11 reveal the relatively low levels of phosphorus removed by 0.45μ filtration. In one case involving stream water (Figure 20), an increase in phosphorus was found after filtration and can only be rationalized by the presence of a phosphorus contaminant in the vacuum filtration flask.

NITROGEN

Profiles for all waters included Kjeldahl, ammonia, and nitrate/nitrite nitrogen analysis. Baseline values (i.e., unfiltred) for raw stream water and wastewater effluent are outlined in Table 12. With exception of the Hatfield tertiary plant which was experiencing operational problems only moderate fluctuations were observed over a 6-month period. The most notable difference between the two types of waters was the relatively high concentration of nitrates in stream water and nitrite levels of the Hatfield (tertiary) effluent (Table 12).

Effectiveness of the three methods of treatment under consideration for removing nitrogen are more demonstrable in treatment plant effluents (Figure 22) than for stream samples (Figure 23) where baseline values are relatively low (See Appendix 1A-1E and Table 13). With minor exceptions alumina contributed nitrogen to stream water, thereby resulting in concentrations greater than control values. Several explanations for this phenomena may be considered. It was first thought that microbial contamination of the column had occurred, but was highly unlikely since all water was being filtered through a 0.48   membrane filter immediately prior to treatment. A more plausible explanation suggests that organic and inorganic nitrogen are loosely bound to alumina, and are readily eluted by addition of subsequent samples to the column. In such a case water containing relatively low levels of nitrogen could elute a sufficient quantity in a single pass of the column to exceed pre-treatment analysis values.

KJELDAHL NITROGEN

Review of data before and after 0.45μ filtration reveals Kjeldahl nitrogen of

Table 12

Comparative Concentrations of Kjeldahl, Ammonia, And Nitrate-Nitrite Nitrogen in Raw Stream Water And Wastewater Prior To Treatment

SOURCE	RANGE - PPM NITROGEN			
	KJELDAHL	AMMONIA	NITRATE	NITRITE
FRENCH CREEK	0.2 - 1.5	0.1 - 0.6	1.5 - 2.4	0.004 - 0.02
TROUT RUN	0.1 - 0.4	0.1	2.0 - 2.3	0.004 - 0.01
VALLEY CREEK	0.1 - 0.2	0.03 - 0.1	2.2 - 2.5	0.01 - 0.02
PHOENIXVILLE (SECONDARY)	22 - 29	15 - 23	0.1 - 0.2	0.01 - 0.09
HATFIELD (TERTIARY)	0.1 - 70.2	0.1 - 64.7	0.1 - 1.7	0.1 - 4.4

Table 13

Summary of Nitrogen Treatment Efficiencies for Water & Wastewater

SOURCE	PARAMETER	RANGE OF % REDUCTION FOLLOWING:		
		ALUMINA ADSORPTION	CAPILLARY DIALYSIS	COAGULATION
FRENCH CREEK	Kjeldahl - N	+	0 - 75	+ - 0
	Ammonia - N	+	+ - 70	+ - 0
	Nitrate - N	+ - 37	86 - 95	0 - 23
	Nitrite - N	+ - 60	0 - 80	+ - 0
VALLEY CREEK	Kjeldahl - N	+ - 0	0 - 66	0 - 33
	Ammonia - N	+ - 0	0 - 60	+
	Nitrate - N	0 - 39	84 - 91	4 - 9
	Nitrite - N	0 - 50	80 - 95	0 - 50
TROUT RUN	Kjeldahl - N	+ - 25	+ - 50	+ - 66
	Ammonia - N	+ - 50	0 - 50	0 - 50
	Nitrate - N	+ - 83	77 - 81	+ - 44
	Nitrite - N	0	+ - 70	+ - 70
HATFIELD (TERTIARY)	Kjeldahl - N	+ - 82	+ - 7	+ - 12
	Ammonia - N	+ - 89	+ - 82	+ - 90
	Nitrate - N	0 - 6	60 - 93	0 - 6
	Nitrite - N	0 - 4	56 - 90	0 - 4
PHOENIXVILLE (SECONDARY)	Kjeldahl - N	92 - 97	84 - 90	+ - 40
	Ammonia - N	97 - 99	71 - 94	0 - 38
	Nitrate - N	+ - 50	0 - 70	+ - 50
	Nitrite - N	0	50 - 80	+ - 12

+ = Exceeds Control ; 0 = Equals Control.

Table 14

Summary of Kjeldahl Nitrogen Removed By 0.45μ Filtration of Stream Water & Wastewater Effluent

SOURCE	SAMPLE NO.	PPM		
		UNFILTERED	FILTERED	REMOVED
FRENCH CREEK	1	0.2	0.2	0
	2	0.2	0.1	0.1
	3	0.3	0.3	0
	4	1.5	0.8	0.7
TROUT RUN	1	0.3	0.4	+ 0.1
	2	0.4	0.3	0.1
	3	0.1	0.2	+ 0.1
VALLEY CREEK	1	0.2	0.2	0
	2	0.2	0.2	0
	3	0.3	0.3	0
	4	0.1	0.1	0
HATFIELD (TERTIARY)	1	70.2	57.0	13.2
	2	0.1	0.1	0
	3	1.8	1.3	0.5
PHOENIXVILLE (SECONDARY)	1	29	25	4
	2	37	29	8
	3	22	20	2

Table 15

Summary of Cation Treatment Efficiencies for Water & Wastewater

SOURCE	PARAMETER	RANGE OF % REDUCTION FOLLOWING:		
		ALUMINA ADSORPTION	CAPILLARY DIALYSIS	COAGULATION
FRENCH CREEK	Ca	95 - 98	46 - 80	+ - 5
	Mg	96 - 98	50 - 72	+ - 20
	K	75 - 92	28 - 76	+
	B	50 - 80	50 - 88	0 - 16
	Si	97 - 98	75 - 79	3 - 27
	Na	+	67 - 79	+ - 6
TROUT RUN	Ca	99	42 - 78	3 - 5
	Mg	98 - 99	61 - 81	0 - 9
	K	85 - 90	80 - 85	+
	B	0 - 93	66 - 80	0 - 60
	Si	60 - 98	74 - 82	5 - 14
	Na	+	8 - 83	+ - 0
VALLEY CREEK	Ca	99	69 - 85	+ - 14
	Mg	95 - 99	76 - 80	+ -
	K	85 - 90	50 - 90	+
	B	0 - 96	70 - 83	+ - 50
	Si	25 - 98	69 - 80	+ - 23
	Na	+	62 - 94	0

+ = Exceed Control Value; 0 = No change.

Table 15 (Cont'd)

Summary of Cation Treatment Efficiencies for Water & Wastewater

SOURCE	PARAMETER	RANGE OF % REDUCTION FOLLOWING:		
		ALUMINA ADSORPTION	CAPILLARY DIALYSIS	COAGULATION
PHOENIXVILLE (SECONDARY)	Ca	99	66 - 69	+ - 27
	Mg	98 - 99	66 - 69	0 - 16
	K	70 - 98	76 - 85	+
	B	80 - 88	58 - 87	+ - 0
	Si	91 - 98	72 - 76	+ - 33
	Na	+ - 27	77 - 80	0 - 1
HATFIELD (TERTIARY)	Ca	98 - 99	36 - 70	1 - 53
	Mg	92 - 99	33 - 72	0 - 4
	K	+ - 96	50 - 75	+
	B	72 - 88	72 - 90	11 - 50
	Si	96 - 98	49 - 73	3 - 16
	Na	+ - 3	48 - 75	4 - 12

+ = Exceed Control Value; 0 = No change

Table 16

Summary of Boron Removed by 0.45 μ Filtration Of Stream Water & Wastewater Effluent

SOURCE	SAMPLE NO.	PPM		
		UNFILTERED	FILTERED	REMOVED
FRENCH CREEK	1	0.1	0.08	.02
	2	0.1	0.1	0
	3	0.1	0.09	.01
	4	0.2	0.2	0
TROUT RUN	1	0.1	0.1	0
	2	0.1	0.1	0
	3	0.3	0.3	0
VALLEY CREEK	1	0.2	0.1	0.1
	2	0.2	0.2	0
	3	0.2	0.1	0.1
	4	0.6	0.6	0
PHOENIXVILLE (SECONDARY)	1	0.6	0.5	0.1
	2	0.9	0.8	0.1
	3	2.2	1.7	0.5
HATFIELD (TERTIARY)	1	0.9	0.9	0
	2	2.0	1.8	0.2
	3	1.0	1.0	0

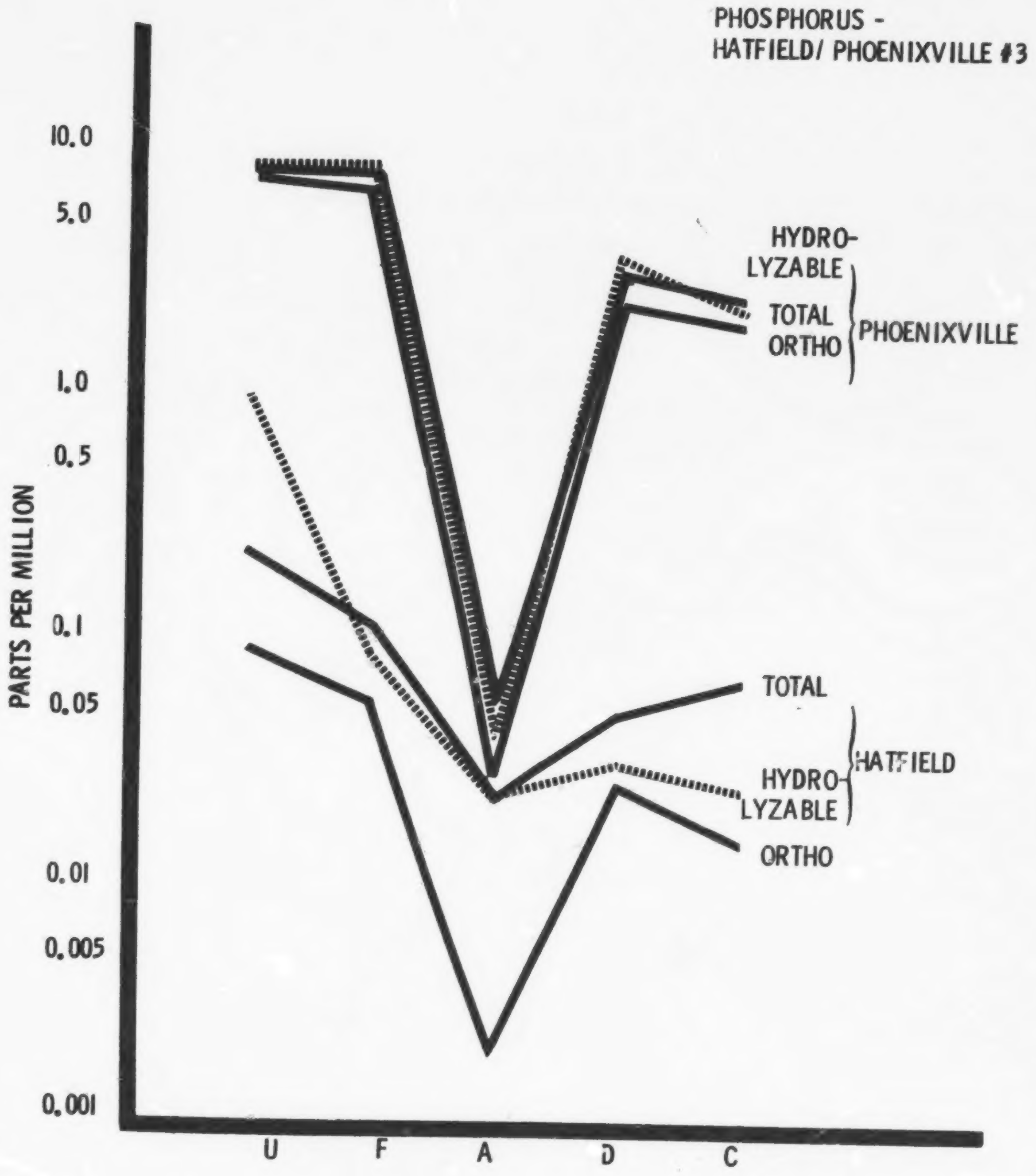

Figure 18. Phosphorus profile of Phoenixville secondary wastewater effluent and Hatfield tertiary wastewater effluent before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

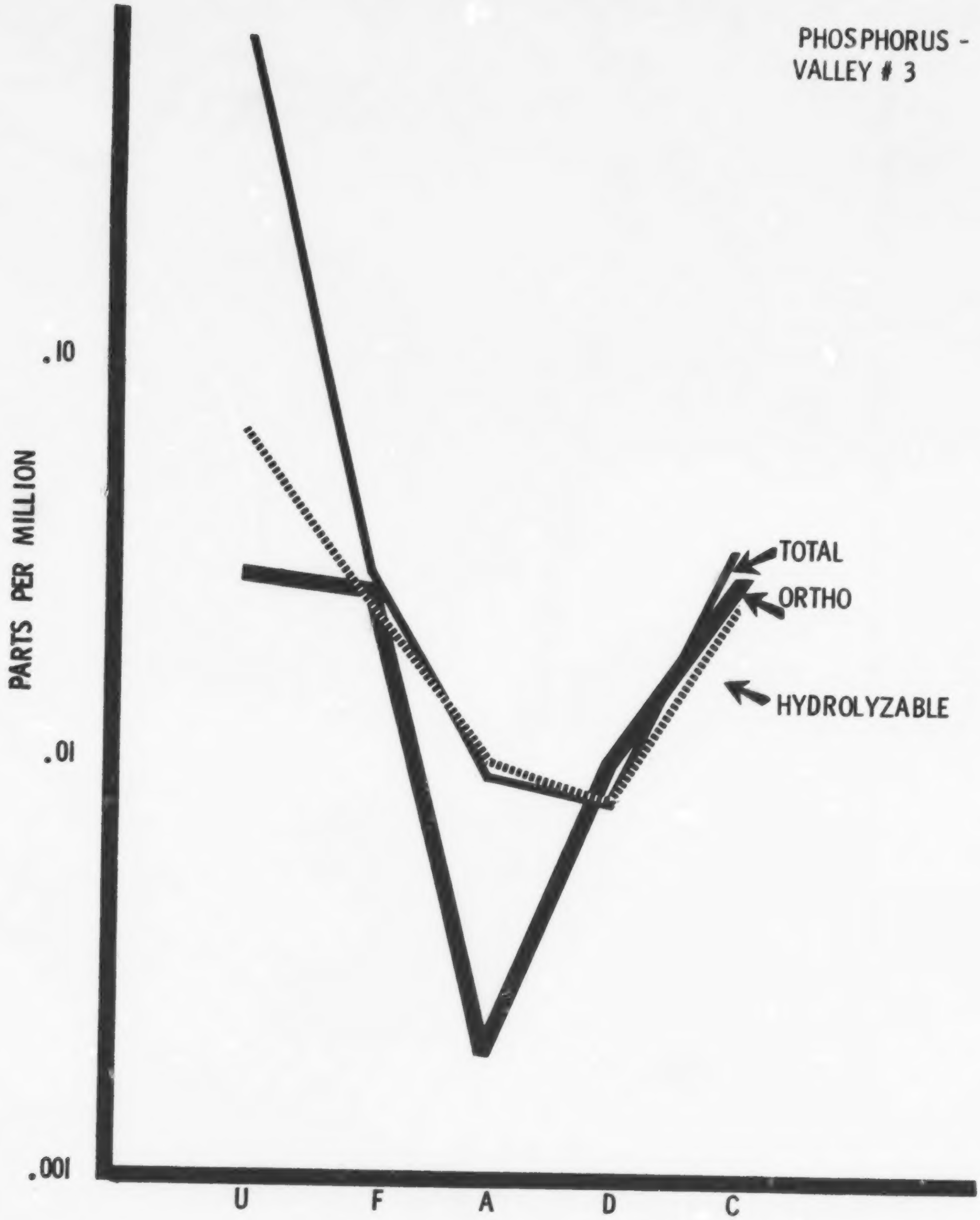

Figure 19. Phosphorus profile of Valley Creek water (collected April 1973) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

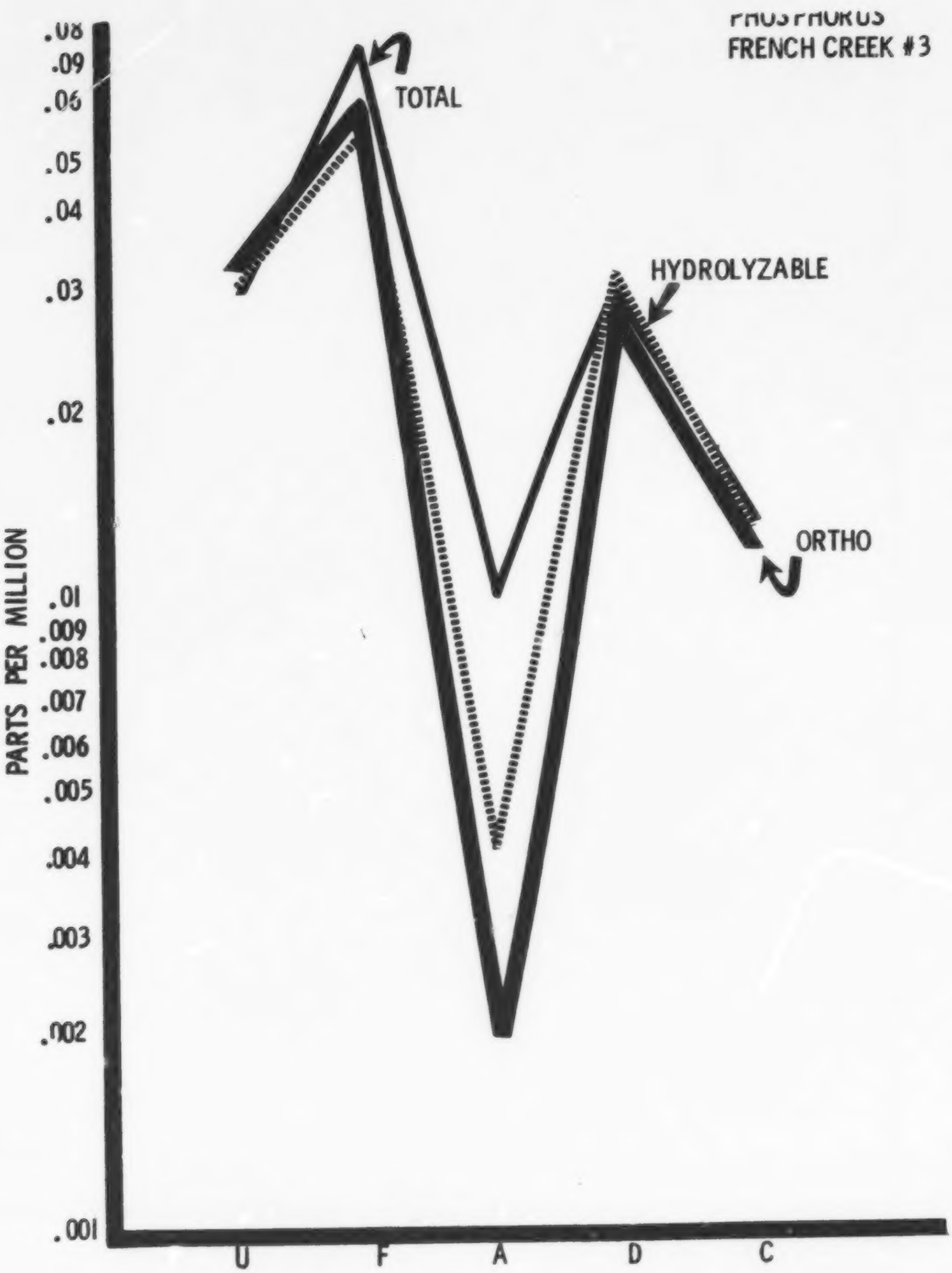

Figure 20. Phosphorus profile of French Creek water (collected April 1973) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorpiton; (D) dialysis; (C) coagulation.

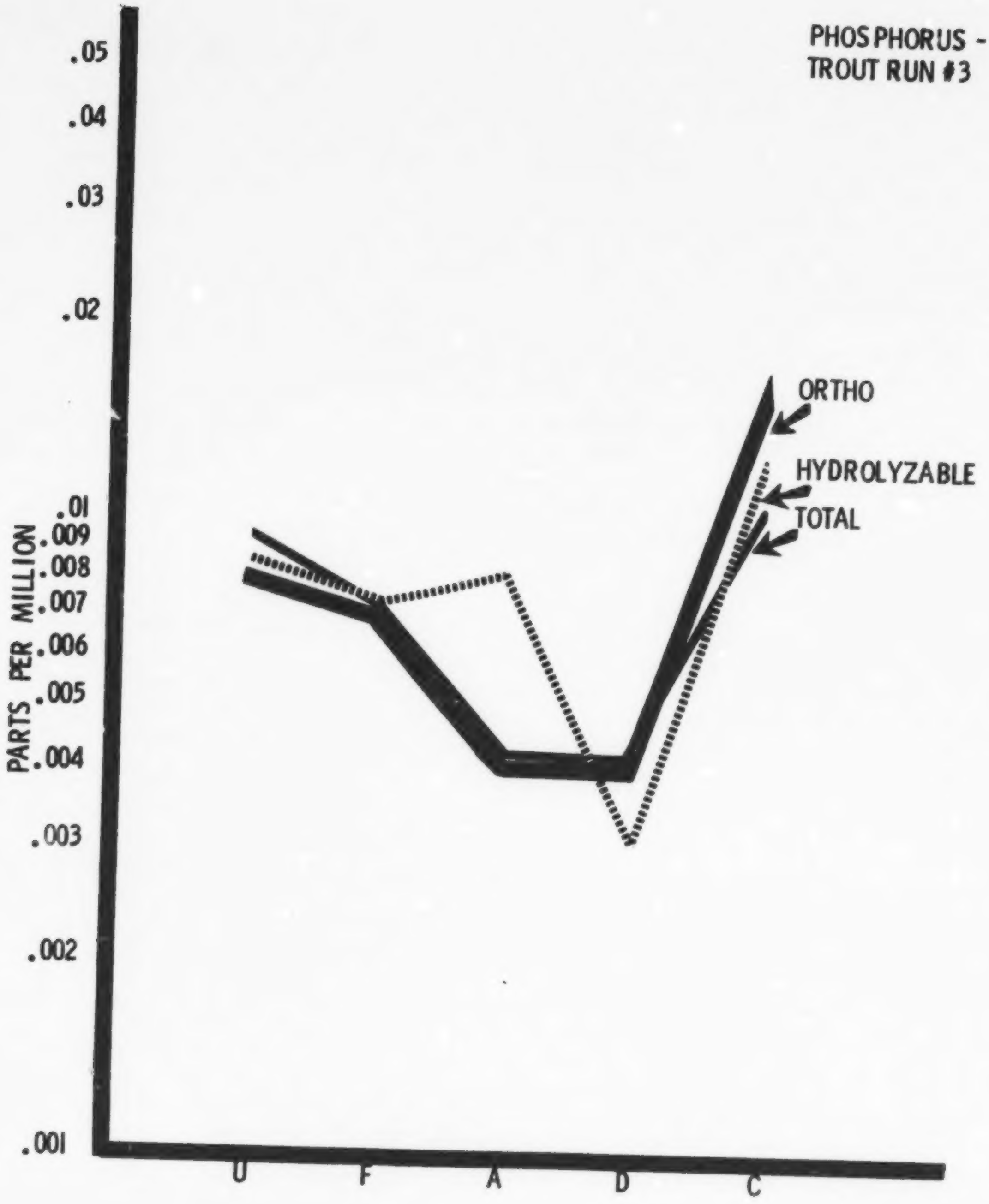

Figure 21. Phosphorus profile of Trout Run water (collected April 1973) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

stream waters to be primarily soluble with minor exceptions (Table 14). Increases observed after filtration in two cases can tentatively be attributed to contaminated glassware, membrane filters (no conclusive proof is available), or possibly technique. As previously alluded to operational problems at Hatfield can account for the relatively high concentration of Kjeldahl nitrogen determined in Sample #1 of Appendix 1E wherease Samples #2 and #3 reflect more realistic values expected for this type of treatment plant.

The Phoenixville secondary treatment effluent in contrast exhibited a pattern of 10-20% insoluable Kjeldahl nitrogen (Table 14).

The efficacy of alumina adsorption and dialysis in removal of Kjeldahl is more obvious in cases where baseline values are consistently high (Table 13 and Figure 22) as reflected in the Phoenixville data. Coagulation, conversely, produced more erratic results and generally was the least effective in the removal of total nitrogen.

AMMONIA NITROGEN

The same pattern was repeated for ammonia nitrogen with alumina removing 92-97% and dialysis 84-90% in 0.45μ filtered Phoenixville effluent. Dialysis appeared to be more effective when lower baseline values were detected but are erratic as can be seen by inspection of Table 13. Coagulation removed 0-38% of Phoenixville ammonia nitrogen and was generally inconsistent with all waters.

NITRATE-NITRITE NITROGEN

Of the three processes, dialysis with minor exceptions, was the most consistent in removal of nitrate nitrogen. This can more readily be observed in stream water where nitrate levels were 10 times higher than in that of the secondary and tertiary treatment plants (Table 12).

Dialysis was also the most effective means of removing nitrite ions (56-90% at Hatfield and 50-80% at Phoenixville) where baseline values were reported to be .01-.09 and 0.1-4.4 ppm, respectively (Tables 12-13). By comparison nitrite removal from stream water fluctuated to a greater extent but can be accounted for by the low concentrations found in French Creek and Trout Run (.01-.004 and .02-.004 ppm, respectively) (Table 12).

Further studies are required to elucidate the effectiveness of dialysis in removal of nitrate-nitrite ions, particularly in low concentrations, but based on the limited experiments it is suggested to be more effective than alumina adsorption or coagulation (Figure 24).

CATIONS

A clear cut picture of the relative effectiveness of alumina adsorption,

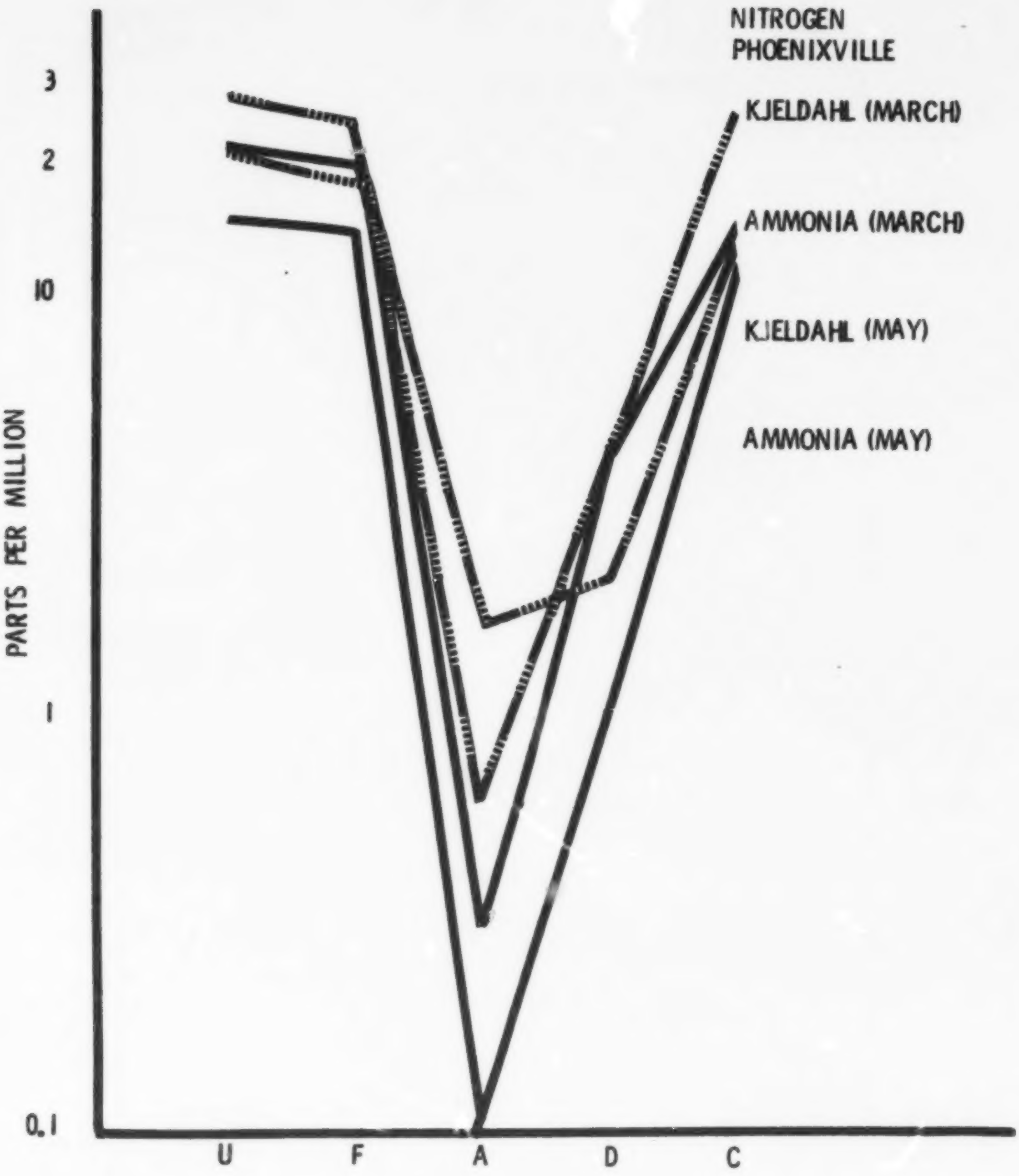

Figure 22. Comparative nitrogen profile (Kjeldahl and ammonia) of Phoenixville secondary wastewater effluent (collected March and May 1973) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

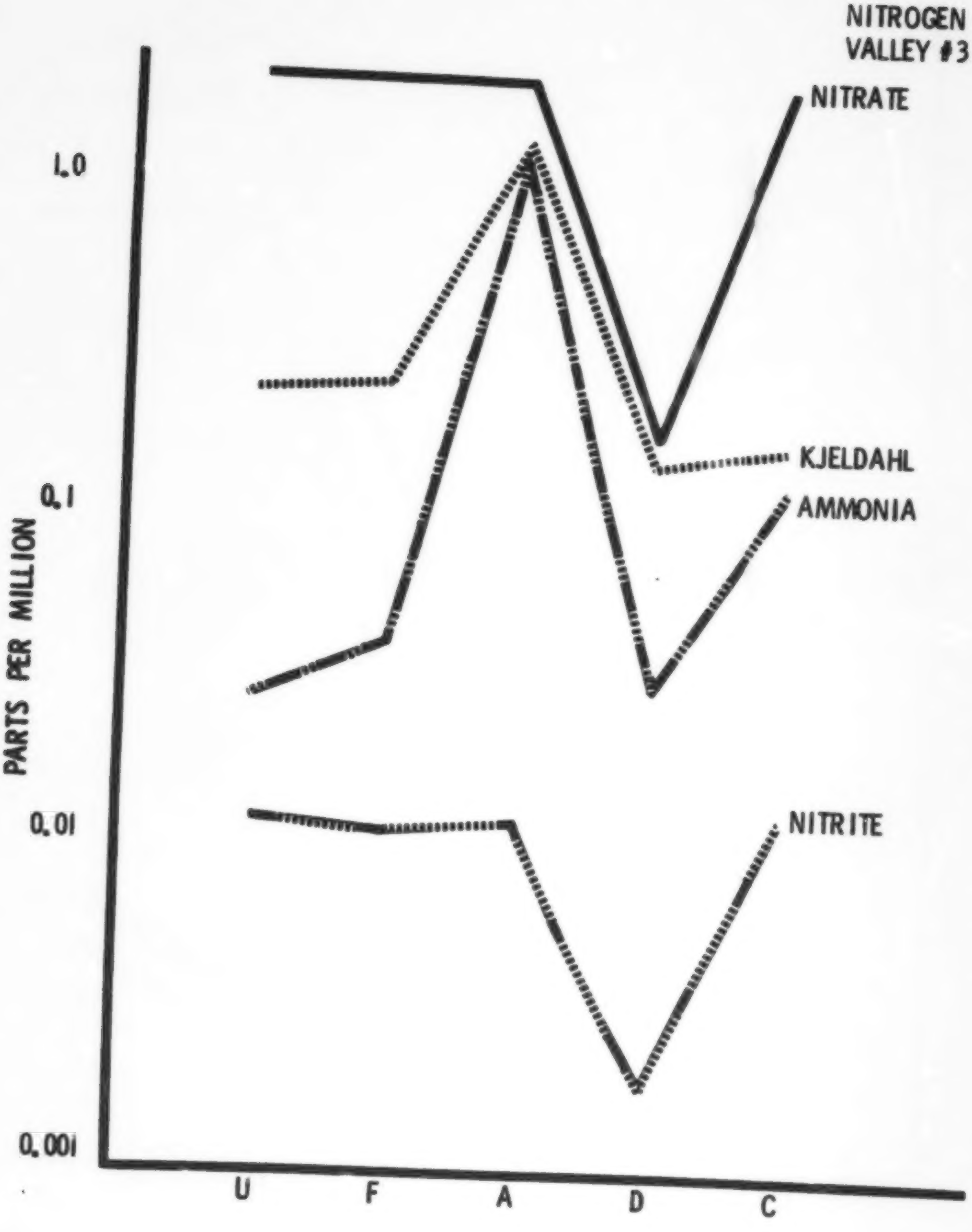

Figure 23. Nitrogen profile of Valley Creek water (collected April 1973) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

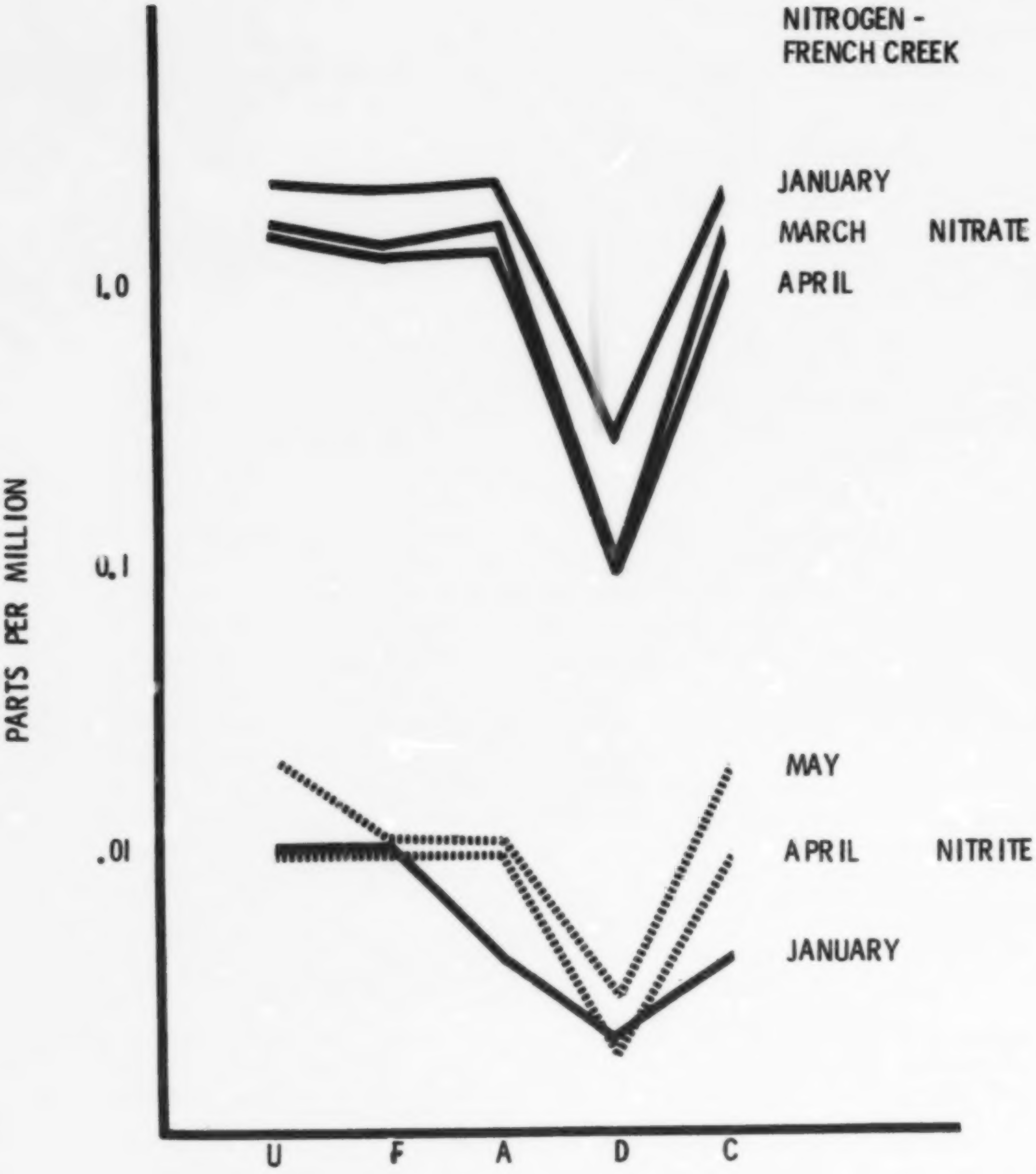

Figure 24. Comparative nitrate-nitrate prifiles of French Creek water samples before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

capillary membrane dialysis, and coagulation evolves in the review of cation data.

CALCIUM AND MAGNESIUM

Calcium and magnesium were removed from all waters by alumina adsorption in the range of 95-99% and 92-99%, respectively (Table 15 and Figures 25-27). In comparison dialysis removed 36-85% of calcium and 33-81% of magnesium.

Coagulation with alum and the polyelectrolyte showed a high degree of variation with calcium ranging from concentrations exceeding control values to a maximum of 53%. Magnesium removal efficiency also varied from values exceeding that of controls to a high of 20% (Table 15).

POTASSIUM

Alumina adsorption accounted for potassium reduction of 75-92% in stream water and 70-98% in wastewater effluent. Capillary dialysis removed 28-90% of this cation from stream samples and 50-85% from wastewater. In all instances potassium derived from the aluminum potassium sulfate appeared in treated samples in concentrations greater than controls.

BORON

Boron was of interest in this study since it is an essential element for plant growth, but in excess concentrations can have a deleterious effect on the growth at levels exceeding 2 ppm[9]. Baseline values following 0.45μ filtration ranged from 0.08 to 0.6 ppm for stream water and 0.5-1.8 ppm in wastewater effluent. The boron content of raw stream water was most generally soluble with a maximum of 0.1 ppm being removed by filtration. Wastewater effluent contained a maximum of 0.5 ppm of insoluble material at Phoenixville and 0.2 ppm at Hatfield (Table 16).

Alumina adsorption removed 50-80% of boron from French Creek waters and 0-93% and 0-96% from Trout Run and Valley Creek, respectively. Eighty-eight percent was removed from Phoenixville effluent and 72-88% from Hatfield.

Dialysis proved to be slightly better in removing 50-88% from all stream samples and 58-90% from wastewater. It is likely that this method could have removed more boron by extension of the dialysis period.

Coagulation produced highly variable results with boron removal efficiencies ranging from greater than control values to a maximum of 60% with stream water and 50% with wastewater.

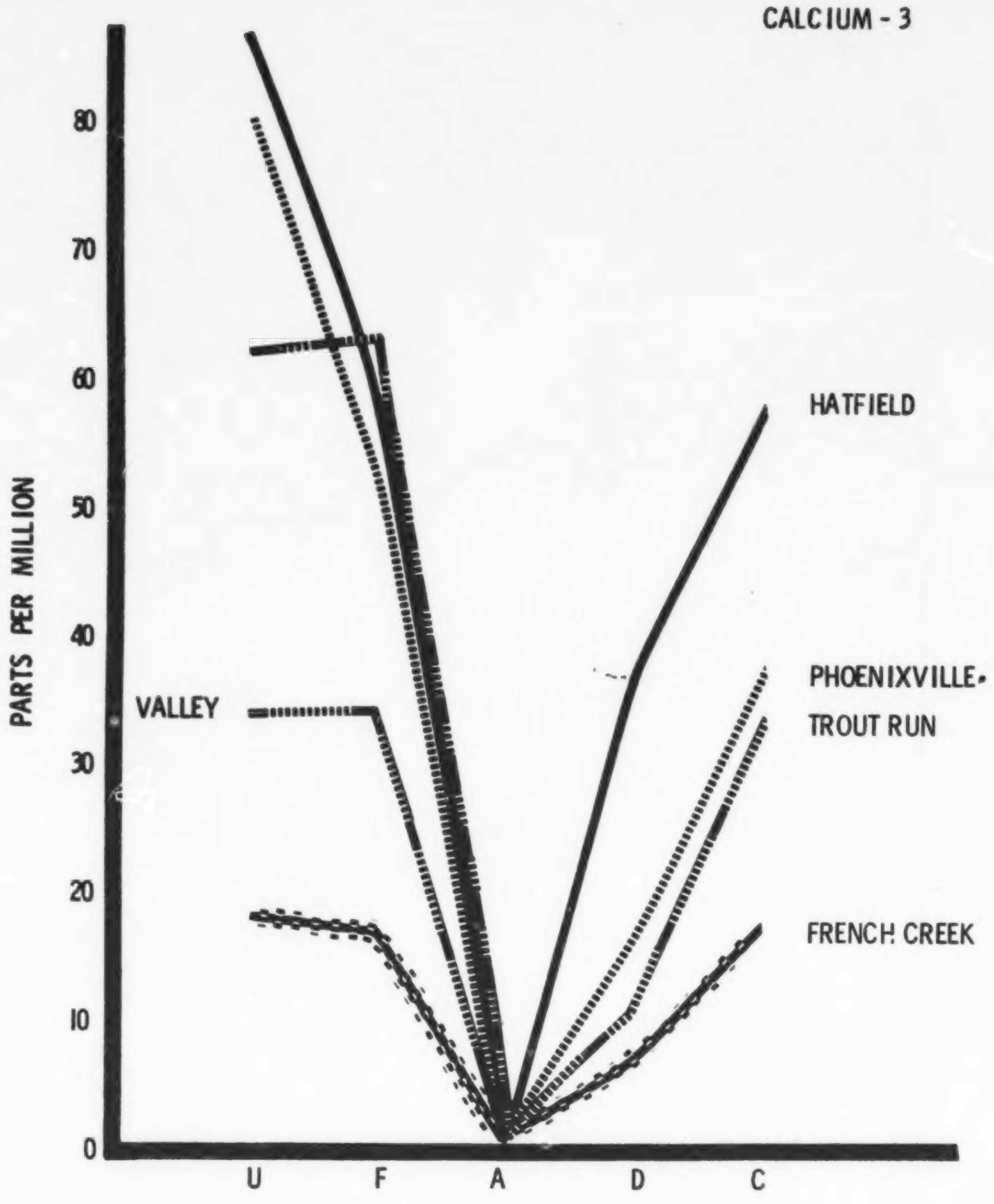

Figure 25. Comparative calcium profiles of water (Valley Creek, French Creek, Trout Run) and wastewater effluent (Phoenixville secondary and Hatfield tertiary) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (C) coagulation.

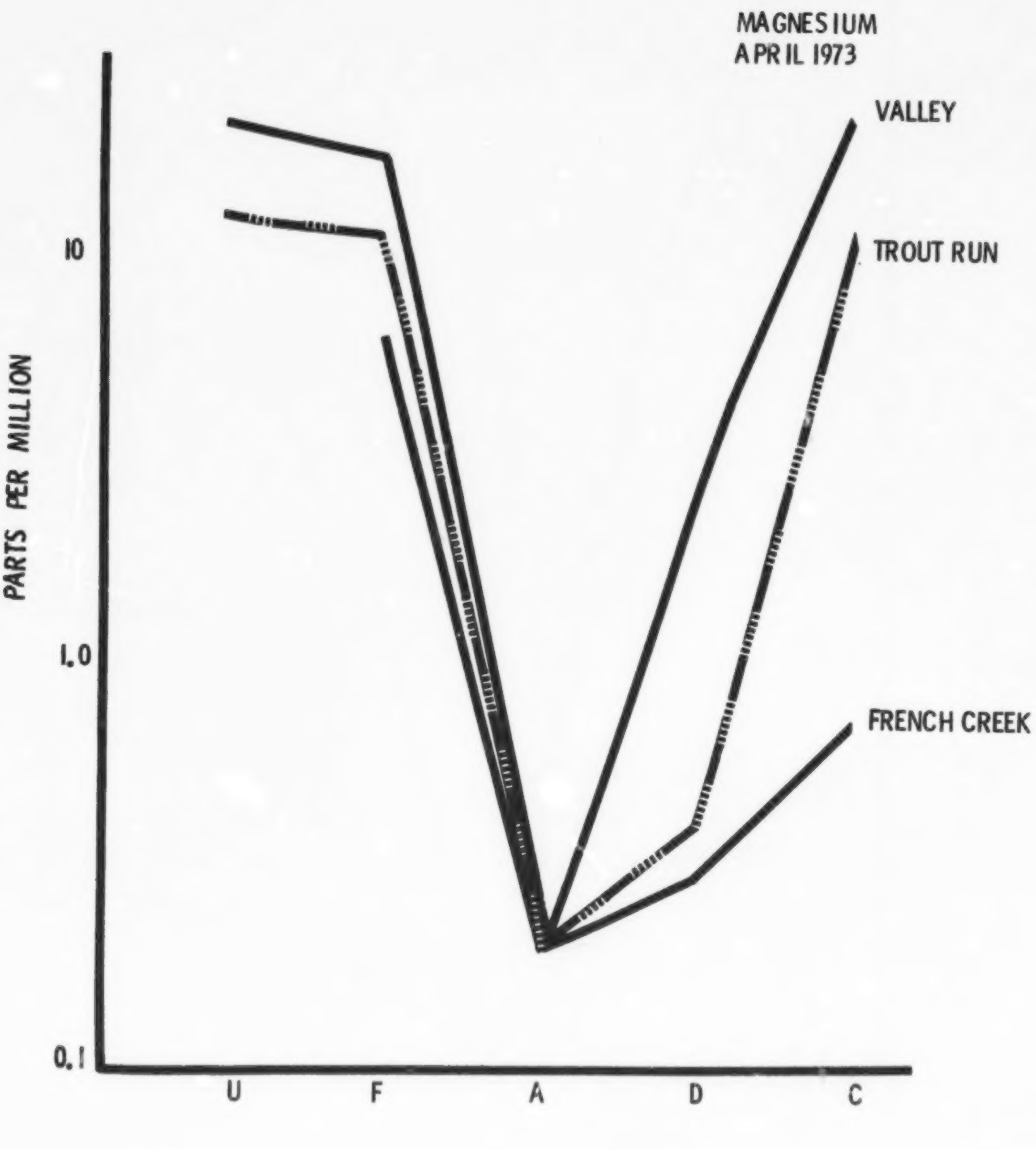

Figure 26. Comparative magnesium profile of water (collected April 1973) from French Creek, Trout Run, and Valley Creek before and after processing.

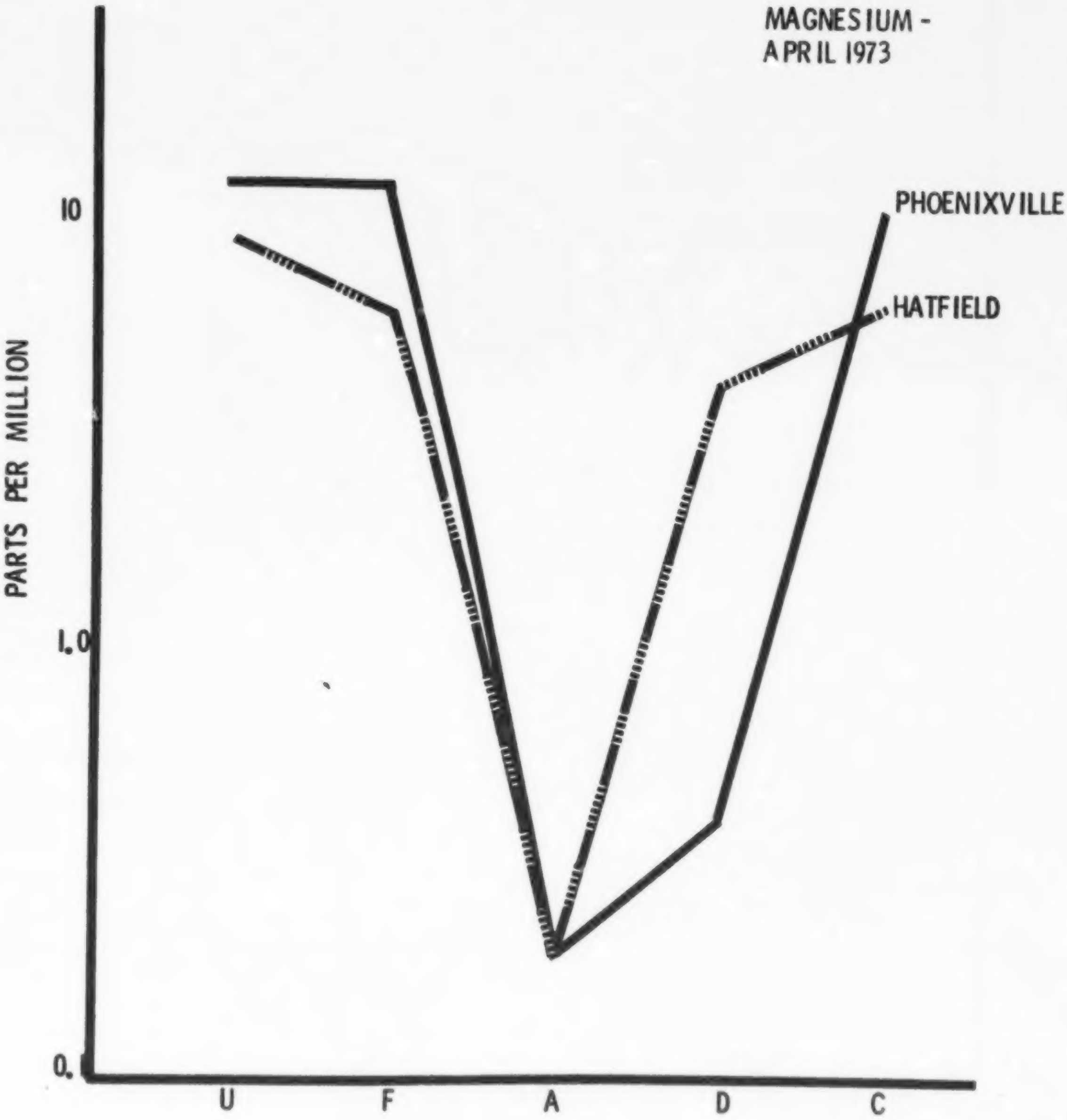

Figure 27. Comparative magnesium profile of Phoenixville (secondary) and Hatfield (tertiary) wastewater effluents (collected April 1973) before and after processing.

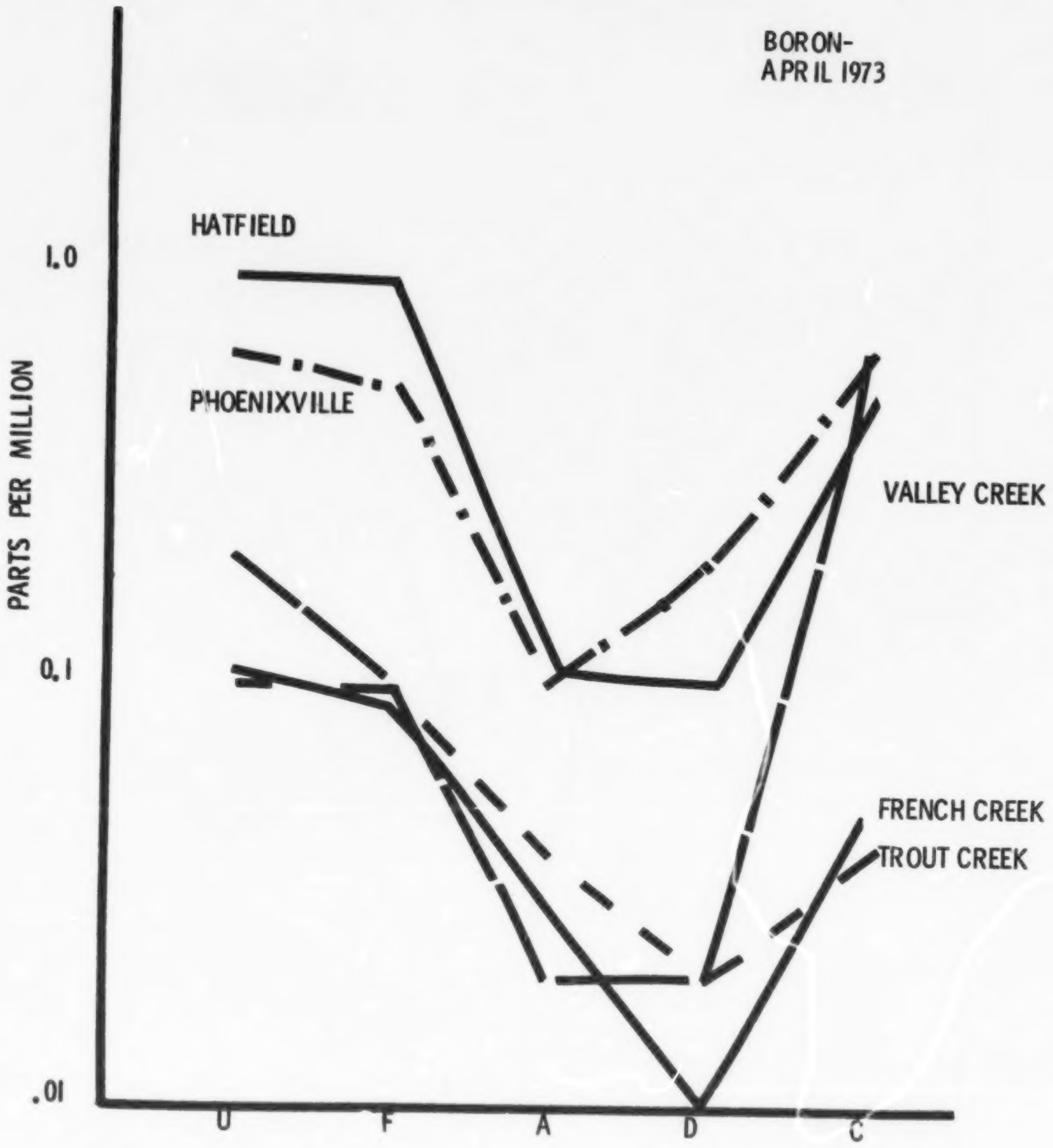

Figure 28. Comparative boron profile of stream water (French Creek, Valley Creek, Trout Run) and wastewater effluent (Phoenixville secondary and Hatfield tertiary collected April 1973) before and after processing.

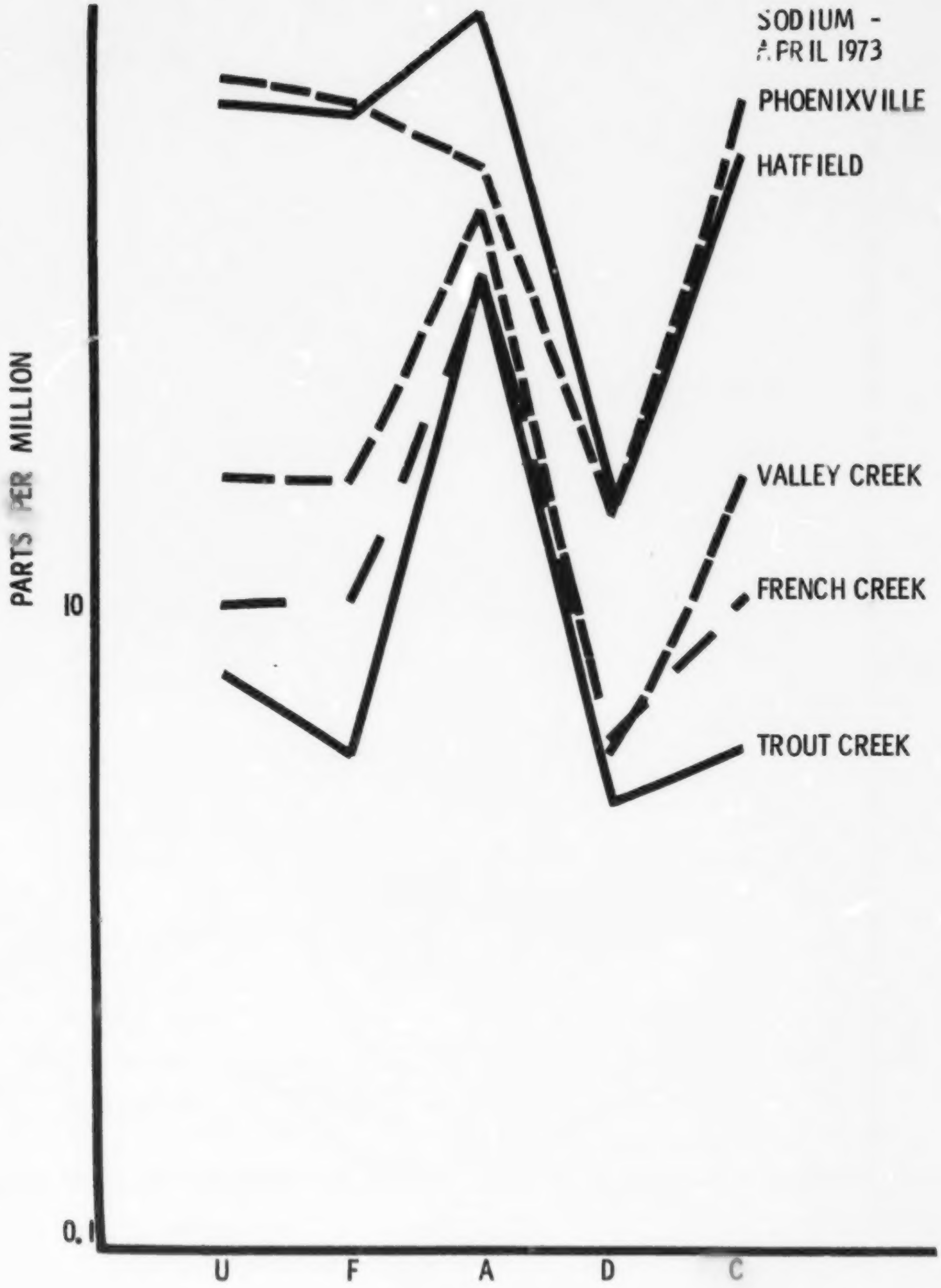

Figure 29. Comparative sodium profiles of stream water (French Creek, Valley Creek, Trout Run) and wastewater effluent (Phoenixville secondary and Hatfield tertiary collected April 1973) before and after processing.

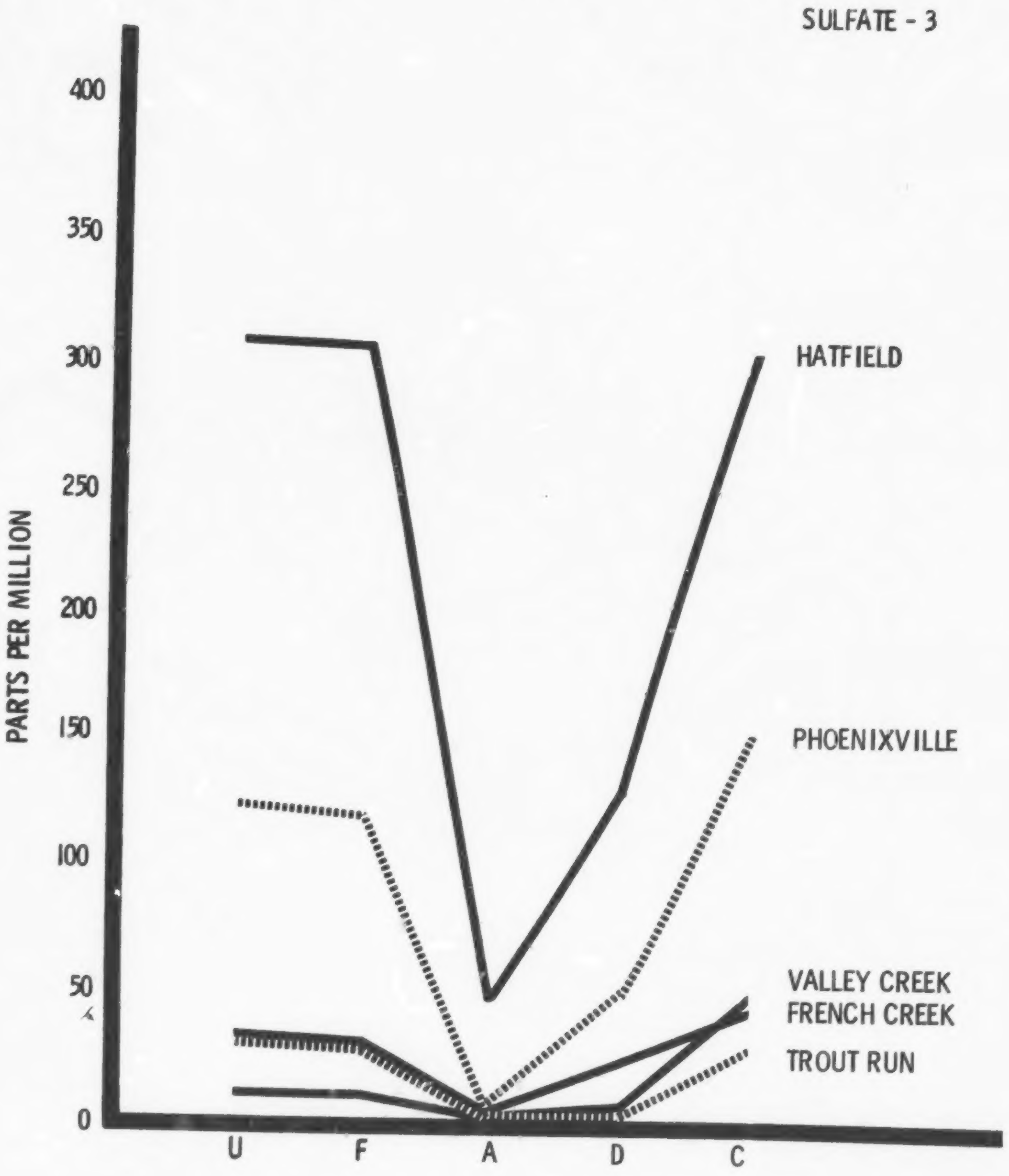

Figure 30. Comparative sulfate profiles of water (Valley Creek, French Creek, Trout Run) and wastewater effluent (Phoenixville secondary and Hatfield tertiary) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (C) coagulation.

SILICA

Silica removal by alumina adsorption from stream water ranged from 97-98% at French Creek, 60-98% at Trout Run, and 25-98% at Valley Creek. For all wastewater this is shown to be in the 91-98 percentile. Overall efficiency of dialysis, in comparison, was 69-80% for stream water and 49-76% for wastewater.

SODIUM

The sodium content of all stream water samples exceeded that of controls. In wastewater effluent this ranged from concentrations exceeding untreated controls to a maximum of 27% at Phoenixville and 3% at Hatfield. This appears to be, as previously discussed, due to sodium from caustic (NaOH) originally used to prepare the column (Figure 29).

Dialysis removed 8-94% from all stream water and 77-80% from wastewater samples. Coagulation treated samples usually showed sodium values higher than controls, and in no instance was more than 12% effective (Table 15).

MISCELLANEOUS CATIONS

Zinc, cobalt, copper, and iron were reported in all samples at or near their detection limit by atomic absorption spectrophotometry. This precluded further analysis of the candidate treatment processes in removing these species from test waters.

ANIONS

Sulfate was effectively removed by alumina adsorption 4-99%; dialysis removed 11-73%; whereas coagulation was completely ineffective. Coagulated samples in fact contained an excess of sulfate, which as discussed for potassium, can be attributed to the use of alum (see Figure 25).

Dialysis was superior for removal of chloride (as high as 84% with stream water and 88% for treatment plant effluent) with alumina and coagulation demonstrating second and third level activity, respectively.

Sulfite could not be satisfactorily evaluated due to the concentration in all samples approaching the minimum detection limit.

MISCELLANEOUS ANALYTICAL PARAMETERS

Specific Conductance

Dialysis was particularly effective in lowering specific conductance (maximum of 82% in stream and 75% in wastewater samples). Alumina generally increased conductance, although in a few cases it was moderately reduced. Increases are probably due to loosely bound species for which the alumina has a low capacity and are readily eluted from the column matrix once breakthrough levels are reached (Figure 31).

Conductance increased in all samples treated with the polyelectrolyte-alum combination. This is also attributed to the alum dissociation and the ionic concentration increasing from failure of all of the coagulant to be involved in floc generation. In all probability this may be minimized by pH optimization, but was not considered in conjunction with the subject study.

Hardness

Reduction in hardness achieved by alumina adsorption characteristically paralleled calcium and magnesium concentrations at the 96-99% level (Figures 25-27). In the case of dialysis hardness fell 23-81% below values for untreated controls. Coagulated samples more frequently increased hardness, although it was reduced in a few cases not more than 6%.

Total Alkalinity

Alkalinity was consistently reduced by dialysis 71-89% in stream water and 62-81% in wastewater effluent (Figure 33). By comparison the alkalinity of alumina treated stream water ranged from values exceeding controls to a maximum reduction of 84%. Treated effluent was more uniform with total alkalinity 70-93% less than controls. The disparity is due to the low initial alkalinity of stream waters (~ 25-150 ppm) and the higher concentration found in effluents (~ 176-255 ppm) compounded by the alkaline nature of the column. Coagulation accounted for a reduction of alkalinity in stream water and effluents of 6-25% and 6-53%, respectively.

pH

Hydrogen ion concentration of stream and watewater effluent before and after 0.45μ filtration and treatment by each of the methods under consideration are summarized in Table 17.

Differences between unfiltered and filtered samples are generally attributable to varying concentrations of total and dissolved solids (Tables 18 & 19) and their individual buffering capacity.

Changes in hydrogen ion concentration occurred most dramatically in alumina treated samples with water and wastewater shifting from baseline values of pH 6.80-8.95 to pH 7.76-10.96. The pH of all samples dropped following dialysis, and to a lesser extent following coagulation. In a

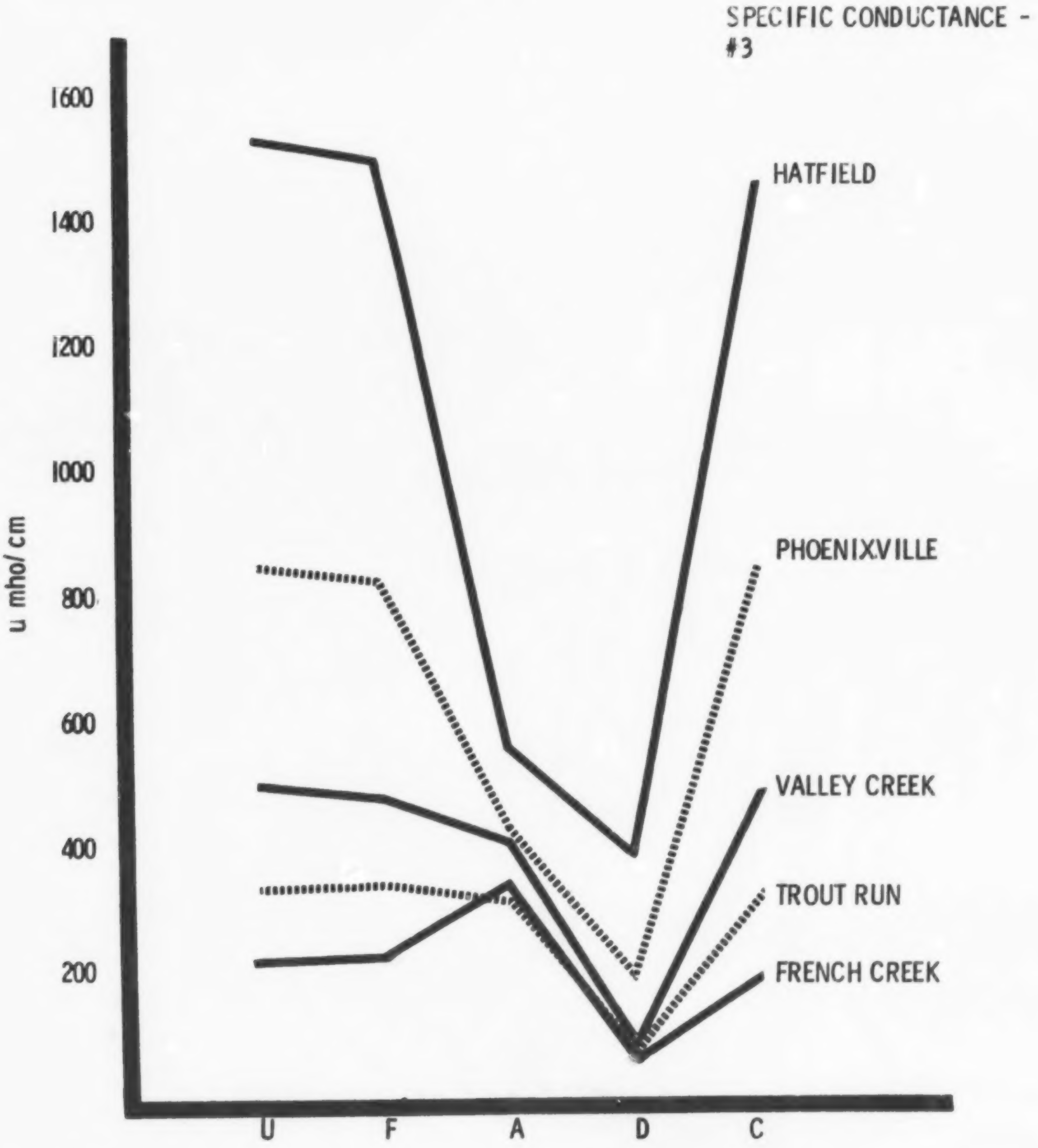

Figure 31. Comparative specific conductance profiles of water (Valley Creek, French Creek, Trout Run) and wastewater effluent (Phoenixville secondary and Hatfield tertiary) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (C) coagulation.

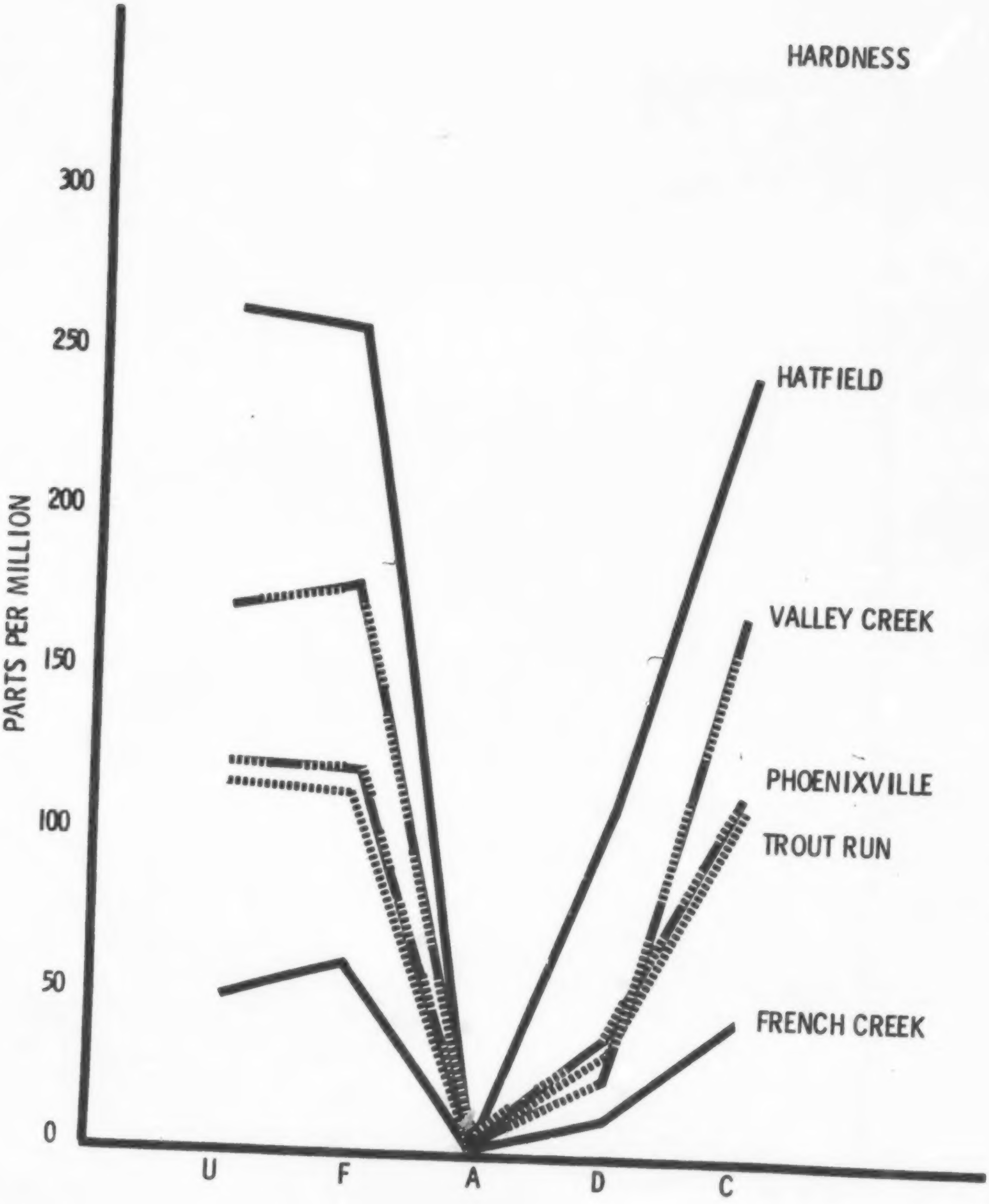

Figure 32. Comparative hardness (EDTA) profiles of water (Valley Creek, French Creek, Trout Run) and wastewater effluent (Phoenixville secondary and Hatfield tertiary) before and after processing. Legend: (U) unfiltered; (F) filtered; (A) alumina adsorption; (C) coagulation.

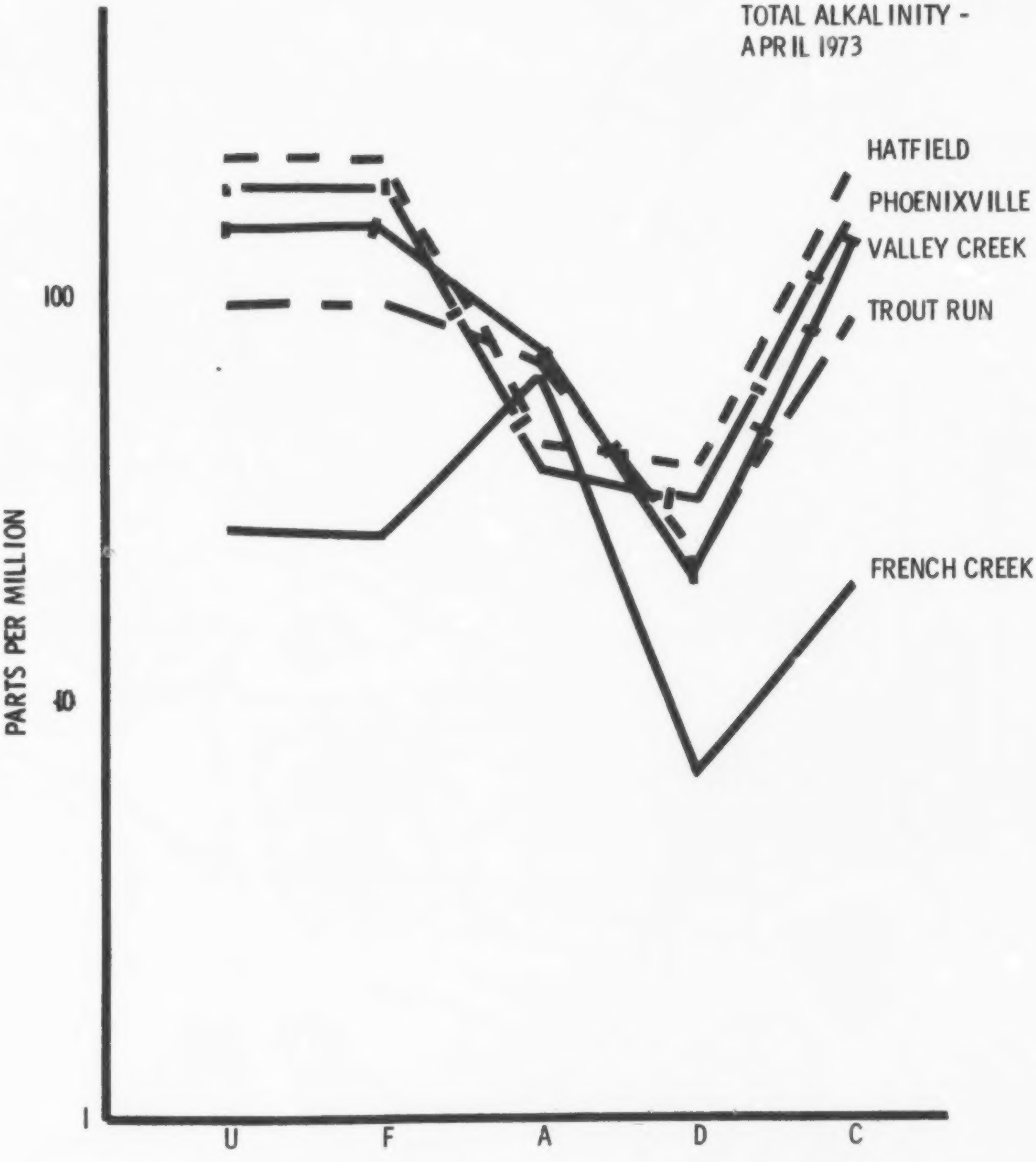

Figure 33. Comparative total alkalinity profiles of water (Valley Creek, French Creek, Trout Run) and wastewater effluent (Phoenixville and Hatfield) before and after processing.

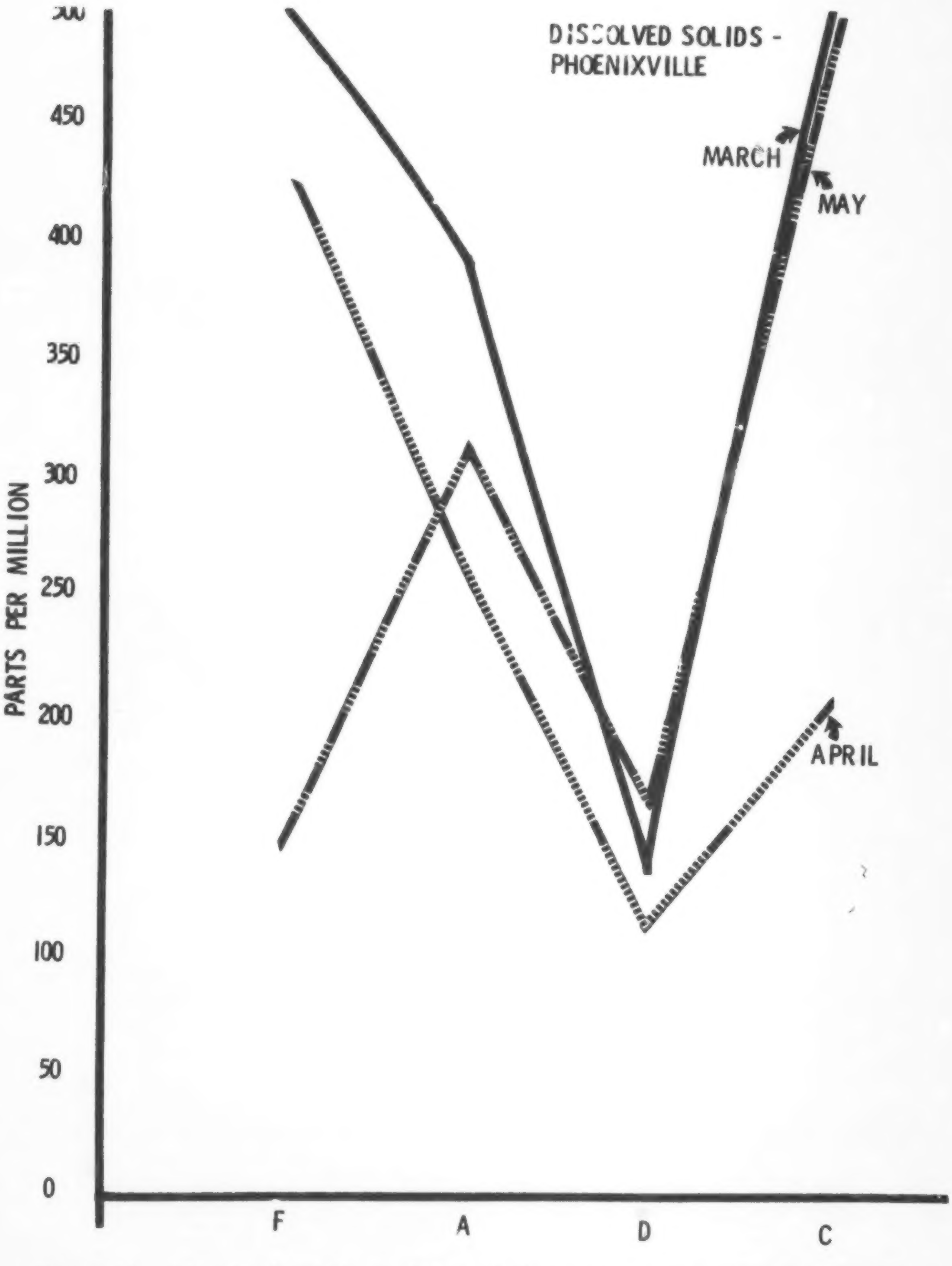

Figure 34. Dissolved solids profiles of Phoenixville secondary wastewater effluent (collected March, April, May 1973) before and after processing. Legend: (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

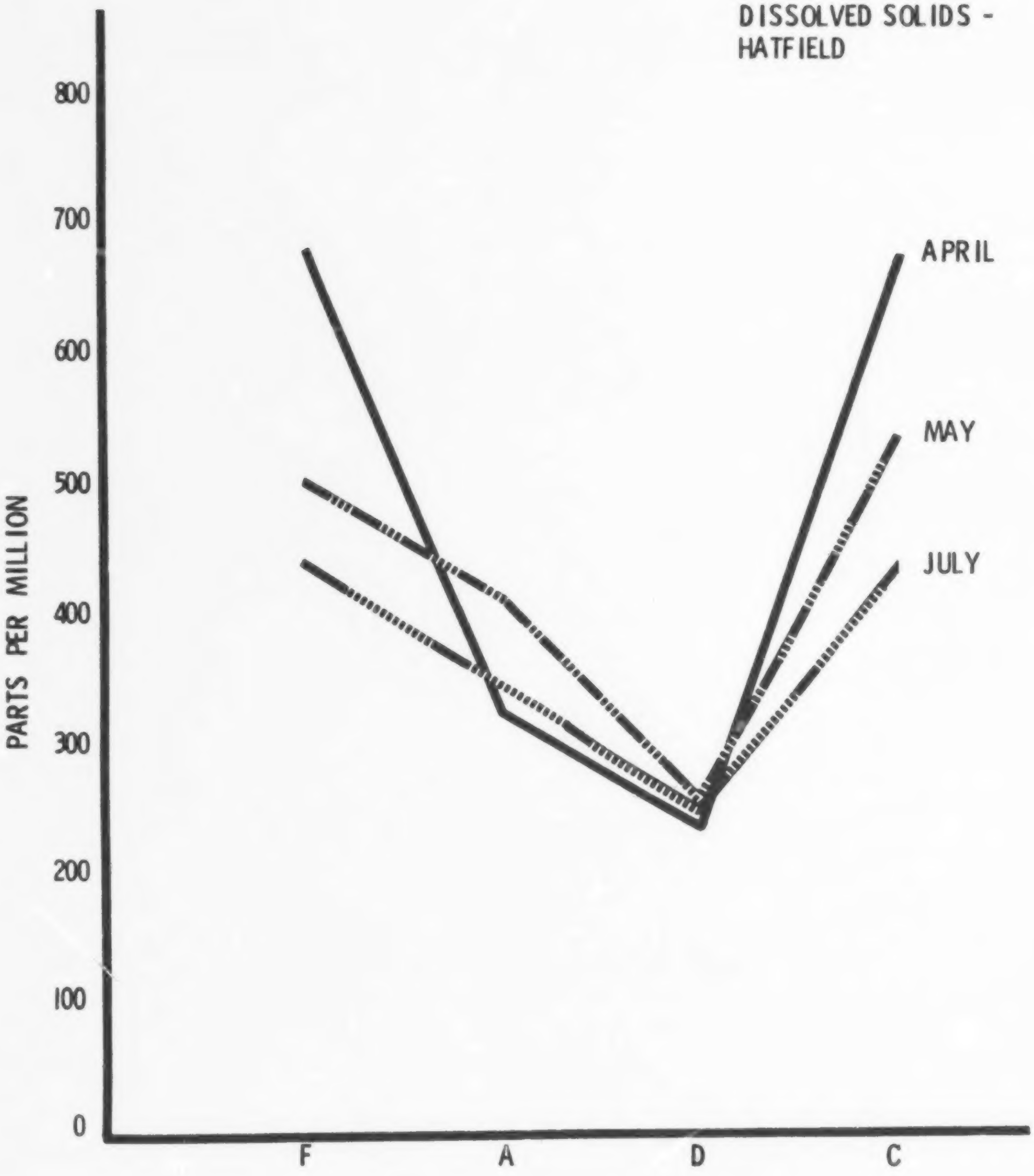

Figure 35. Dissolved solids profiles of Hatfield tertiary wastewater effluent (collected April, May, July 1973) before and after processing Legend: (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

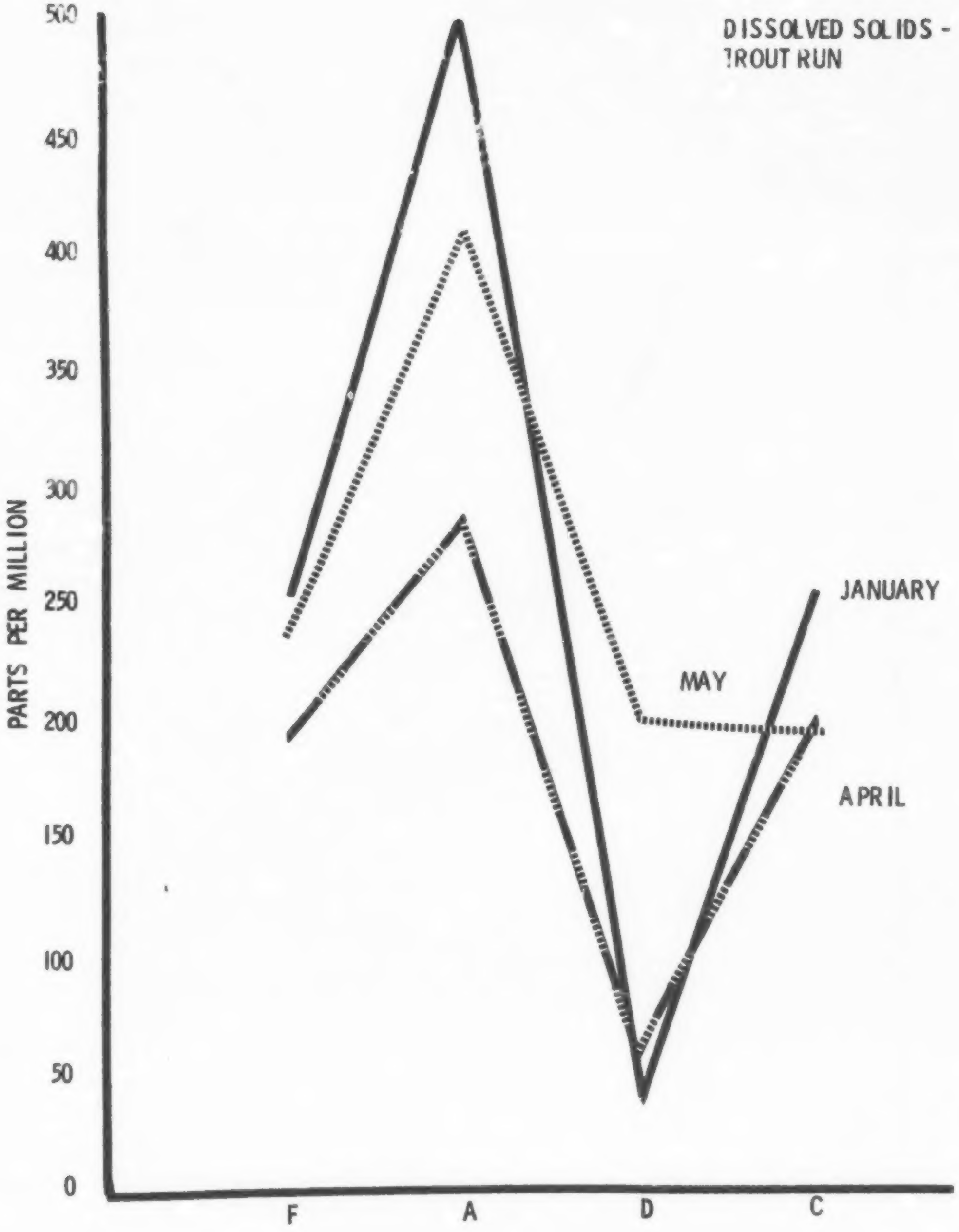

Figure 36. Dissolved solids profiles of Trout Run water (collected January, April, May 1973) before and after processing. Legend: (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

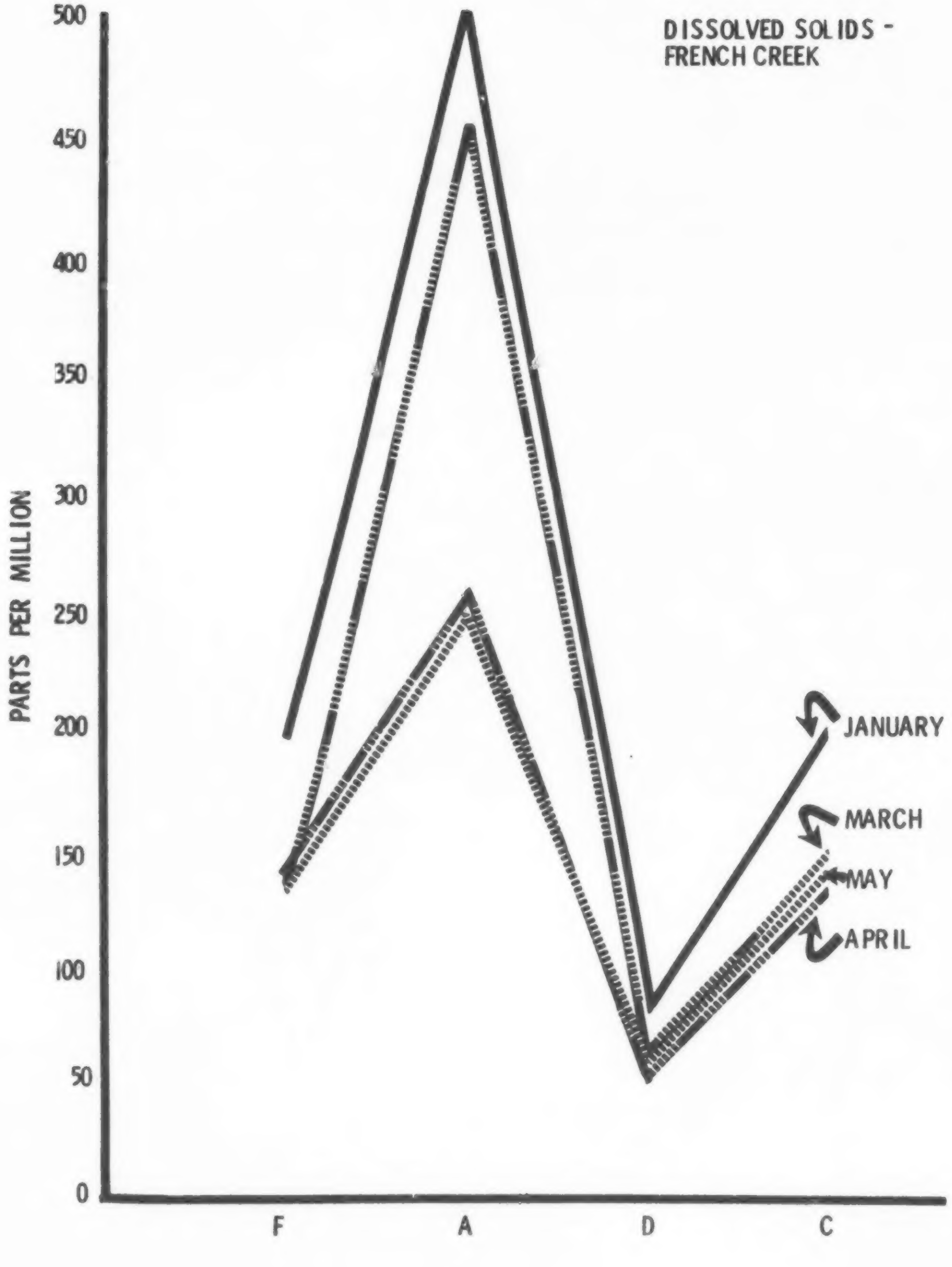

Figure 37. Dissolved solids profiles of French Creek water (collected January, March, April, May 1973) before and after processing. Legend: (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

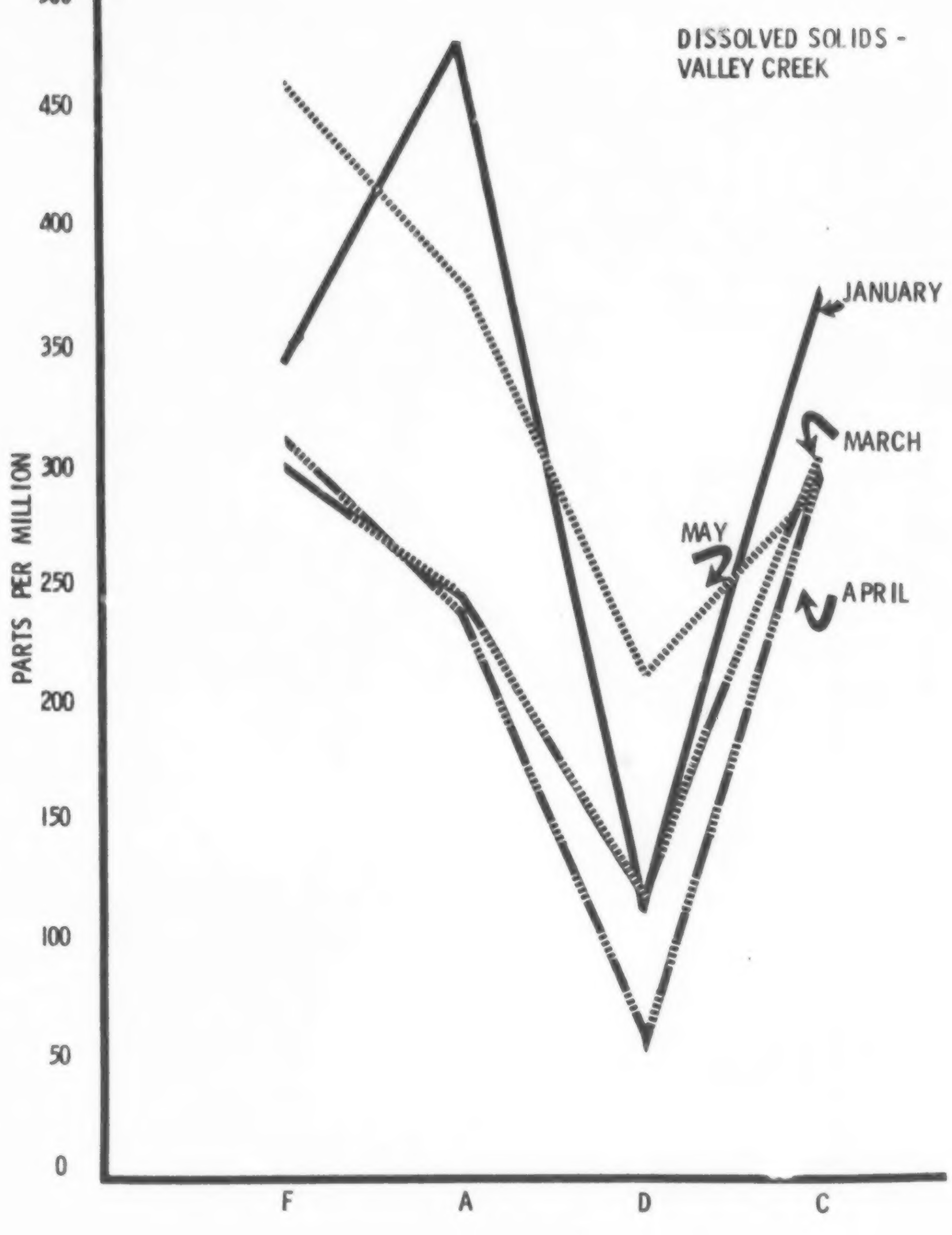

Figure 38. Dissolved solids profiles of Valley Creek water (collected January, March, April, May 1973) before and after processing. Legend: (F) filtered; (A) alumina adsorption; (D) dialysis; (C) coagulation.

few cases a rise in pH occurred with coagulation and is probably due to differences in buffer capacity of specific samples.

Dissolved Solids

Dissolved solids burden of 0.45μ filtered water ranged from 418-688 ppm at Hatfield; 150-497 at Phoenixville; 299-463 ppm at Valley Creek; 191-252 ppm at Trout Run; and 131-183 ppm at French Creek (Table 18).

Dialysis achieved 62-79% reduction of dissolved solids at French Creek; 15-92% at Trout Run; and 51-80% with Valley Creek samples. Of wastewater effluents treated 71-74% removal occurred with Phoenixville samples and 42-67% for those from the Hatfield plant.

In comparison dissolved solids content of alumina treated stream waters either exceeded control values or exhibited a maximum of 28% removal. This efficiency increased to 18-52% with wastewater effluent in which the control values of untreated samples were considerably higher than those found in streams. Again the alumina is suspected of contributing to the dissolved solids levels when early "breakthrough" occurs with the less tenaciously bound species. Coagulation is also unpredictable in controlling dissolved solids, but for the most part increases concentrations considerably above control levels.

It was of interest to plot data for all samples of water and wastewater treated in Figures 35-38. Here can be seen the dramatic reduction of dissolved solids as well as the retention of higher molecular weight species, i.e., > MW 5000. This is quite notable in effluent derived from the tertiary facility (Hatfield) where the dissolved solids retained after dialysis are present in concentrations of ~ 250-275 ppm; those from the secondary plant (Phoenixville) range from ~ 50-75% of dissolved solids following dialysis (Figure 32); whereas Valley Creek demonstrated greater scatter in the same time span (January-May 1973) of ~ 50-210 ppm (Figure 33). Trout Run data is also in the same range except for the relatively low efficiency (15%) achieved following dialysis of the May samples. No other explanation can be made for this discrepancy other than an unknown variation in technique or mix-up in samples.

This data, although preliminary in nature, suggests the retention of macromolecules and/or complexes which could influence algal assays by stimulatory or inhibitory effects on the test organism and compound the problem of comparing assay data from different waters with controls propagated on a chemically defined medium. In all likelihood we may not have completely removed the < 5000 MW fraction in the forty-five minute dialysis period, although this can only be confirmed in studies where serial samples are taken and analyzed to determine when the dissolved solids curve plateaus. An advanced study would also use a series of

Table 17

Summary of Hydrogen Ion Changes Following Treatment of Stream Water and Wastewater

		pH					
SOURCE	SAMPLE NO.	UNFILTERED	FILTERED	Δ pH	ALUMINA ADSORPTION	DIALYSIS	COAGULATION
FRENCH CREEK	1	-	7.14	-	10.57	6.49	6.92
	2	6.92	7.30	+ .38	10.96	7.00	7.30
	3	6.89	6.80	.09	10.22	6.60	6.60
	4	7.65	8.20	+ .55	10.05	6.40	6.85
TROUT RUN	1	-	8.64	-	10.29	7.31	8.10
	2	8.51	8.35	.16	10.54	6.83	7.62
	3	7.60	8.25	.65	10.20	7.30	7.65
VALLEY CREEK	1	-	8.95	-	11.25	7.14	8.38
	2	7.00	8.30	+ 1.3	7.75	7.02	11.09
	3	9.08	8.77	.31	10.22	6.89	8.38
	4	8.35	8.40	+ .05	9.70	6.95	8.10
PHOENIX-VILLE (Secondary)	1	7.61	8.05	.44	10.96	7.85	7.78
	2	7.72	7.68	.04	9.28	7.30	7.76
	3	7.95	8.05	+.1	9.25	7.85	7.90
HATFIELD	1	7.84	7.76	.08	9.73	7.39	7.81
	2	8.10	7.95	.15	9.65	6.75	7.85
	3	7.98	7.89	0	9.45	7.81	8.70

Table 18

Summary of Total Solids in Raw Stream Water Prior to Filtration

SOURCE	SAMPLE	PPM TOTAL SOLIDS
FRENCH CREEK	1	181
	2	145
	3	130
	4	148
TROUT RUN	1	179
	2	186
	3	217
VALLEY CREEK	1	340
	2	350
	3	520
PHOENIXVILLE	1	340
	2	406
	3	715
HATFIELD	1	666
	2	490
	3	433

Table 19

Summary of Dissolved Solids Treatment Efficiencies for Water and Wastewater

SOURCE	SAMPLE	PPM DISSOLVED SOLIDS IN FILTERED SAMPLES	% REDUCTION FOLLOWING:		
			ALUMINA ADSORPTION	CAPILLARY DIALYSIS	COAGULATION
FRENCH CREEK	1	183	+	79	+
	2	131	+	59	+
	3	132	+	47	2
	4	140	+	62	43
TROUT RUN	1	252	+	92	+
	2	191	+	62	+
	3	236	+	15	15
VALLEY CREEK	1	344	28	67	+
	2	299	19	59	1.4
	3	308	23	80	4.3
	4	463	19	51	37
PHOENIX-VILLE	1	497	21	71	+
	2	421	39	73	50
	3	150	51	74	23
HATFIELD	1	668	52	67	0.1
	2	449	18	34	+
	3	418	18	42	+

+ = Exceeds Control Value.

membranes with different molecular weight cutoffs, e.g., 200-30,000, to identify fraction which could have the most deleterious effect on algal assay test organisms. This could furthermore be tested with stream and wastewater effluents with and without the addition of organic and inorganic compounds of varying molecular weight.

Residual organics in water-supply sources or domestic sewage are generally determined on a gross basis in terms of BOD, COD, or TOC and CCE-CAE, respectively[5]. In 1970 the A.D. Little Company documented all the organic compounds, which had been found or were suspected of being in freshwater, to survey their toxicological characteristics. Of 496 compounds reported in the survey only 66 have been identified[11] Rosen et al detected 77 compounds in primary effluent (of which 18 were identified) and 38 compounds in the secondary effluent of municipal sewage with high resolution anion-exchange chromatography. This study further suggested that other compounds were being synthesized during secondary treatment[12].

Fractionation of organics in secondary effluents by Rebhun and Manka[13] revealed $>50\%$ to be humic substances (humic, fulvic, and hymathomelanic acid) with fulvic acid per se being the predominant species. The remainder consisted of $\sim 8.3\%$ ether extractables, $\sim 13.9\%$ anionic detergents; $\sim 11.5\%$ carbohydrates; $\sim 22.4\%$ proteins; and $\sim 1.7\%$ tanins. A recent investigation of organics in the Charles River, Boston, by gas chromatography/mass spectrometry techniques detected the presence of normal alkanes (C_{15} to C_{31}), alkyl naphthalenes, alkyl anthracenes or phenanthrenes, pyrene fluoranthene, dibutyl phthalate, and di (2-ethylhexyl) phthalate. Although the effects of many of these materials in trace concentrations on the algal assay are unknown, it is highly suggestive that their potential presence must be taken into consideration in analyses of assay data and development of advanced methods for preparing a basal assay medium.

SECTION VII

ACKNOWLEDGEMENTS

Personnel of the General Electric Company's Biological and Chemical Sciences Laboratory who participated in this study were Roland J. Starkey, Jr., Mary E. Kub, Albert E. Binks, and Kamlesh K. Jain. Secretarial services were supplied by (Mrs.) Linda Koutsonikas and (Mrs.) Madeline Sowers. The U.S. Environmental Protection Agency Project Officer was Thomas E. Maloney.

Cooperation of personnel at the Phoenixville and Hatfield waste treatment facilities expedited collection and processing of effluent samples. Without their help this study would not have been possible.

SECTION VIII

REFERENCES

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APPENDIX I

I-A. Comparative Analysis of Stream Water Before and After Treatment by Alumina Adsorption, Capillary Membrane Dialysis, and Coagulation: French Creek.

I-B. Comparative Analysis of Stream Water Before and After Treatment by Alumina Adsorption, Capillary Membrane Dialysis, and Coagulation: Trout Run.

I-C. Comparative Analysis of Stream Water Before and After Treatment by Alumina Adsorption, Capillary Membrane Dialysis, and Coagulation: Valley Creek.

I-D. Comparative Analysis of Stream Water Before and After Treatment by Alumina Adsorption, Capillary Membrane Dialysis, and Coagulation: Phoenixville Secondary Treatment Plant.

I-E. Comparative Analysis of Stream Water Before and After Treatment by Alumina Adsorption, Capillary Membrane Dialysis, and Coagulation: Hatfield Tertiary Treatment Plant.

APPENDIX I-1A

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

FRENCH CREEK

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% ΔR*	CAPILLARY MEMBRANE DIALYSIS	% ΔR*	COAGULATION: ALUM POLY-ELECTROLYTE	% ΔR*
NUTRIENTS	TOTAL CARBON	1	JANUARY	5	10	12	+	5	50	10	0
		2	MARCH	11	10	6	40	6	40	9	10
		3	APRIL	11	12	8	33.4	8	33.4	11	8.4
		4	MAY	19	15	10	33.4	9	40.0	13	14
	ORGANIC CARBON	1	JANUARY	1	2	6	+	2	0	4	+
		2	MARCH	6	6	3	50	5	17	7	+
		3	APRIL	4	5	3	40	5	0	5	0
		4	MAY	8	5	3	40	6	+	5	0
	INORGANIC CARBON	1	JANUARY	4	8	6	25	3	62.5	6	25
		2	MARCH	5	4	3	25	1	75.0	3	25
		3	APRIL	7	7	5	28.6	3	57.2	6	14.3
		4	MAY	11	10	7	30	3	70	8	20
	TOTAL PO_4 - P	1	JANUARY	0.6	0.05	0.002	96	0.06	+	0.002	96
		2	MARCH	0.04	0.04	0.01	75	0.01	75	0.01	75
		3	APRIL	0.03	0.07	0.01	85.8	0.03	57.2	0.02	71.5
		4	MAY	0.05	0.05	<0.005	>90	0.02	60	< 0.005	>90
	HYDROLYZABLE PO_4 - P	1	JANUARY	0.06	0.04	0.01	75	0.05	+	0.01	75
		2	MARCH	0.04	0.04	0.01	75	0.004	90	0.01	75
		3	APRIL	0.03	0.05	0.004	92	0.03	40	0.02	60
		4	MAY	0.04	0.05	< 0.005	> 90	0.02	60	< 0.003	90
	PHOSPHATE ORTHO	1	JANUARY	0.03	0.01	< 0.002	80	0.04	+	0.004	60
		2	MARCH	0.03	0.03	0.01	66.7	0.01	66.7	0.01	66.7
		3	APRIL	0.03	0.06	0.002	96.7	0.03	50	0.01	83.4
		4	MAY	0.04	0.05	< 0.005	90	0.02	60	<0.005	90
	KJELDAHL NITROGEN	1	JANUARY	0.2	0.2	0.4	+	0.2	0	0.2	0
		2	MARCH	0.2	0.1	5.2	+	0.1	0	0.5	+
		3	APRIL	0.3	0.3	0.5	-	0.2	33.4	0.3	0
		4	MAY	1.5	0.8	1.3	+	0.2	75	0.8	0

* Expressed as % reduction of filtered samples + Value of treated sample exceeds that of filtered control † Values reported are near limit of sensitivity for tes

APPENDIX I-IA

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION;

FRENCH CREEK

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% ΔR*	CAPILLARY MEMBRANE DIALYSIS	% ΔR*	COAGULATION: ALUM POLY-ELECTROLYTE	% ΔR*
NUTRIENTS	AMMONIA NITROGEN	1	JANUARY	0.1	0.1	0.2	+	0.1	0	0.1	0
		2	MARCH	0.1	0.1	5.0	+	0.1	0	0.4	+
		3	APRIL	0.1	0.1	0.3	+	0.03	70	0.1	0
		4	MAY	0.6	0.04		+	0.2	+	0.2	+
	NITRATE NITROGEN	1	JANUARY	2.3	2.2	2.3	+	0.3	86.4	2.0	9.1
		2	MARCH	1.6	1.4	1.6	+	0.1	92.9	1.4	0
		3	APRIL	1.5	1.3	1.3	0	0.1	92.4	1.0	23.1
		4	MAY	2.4	2.4	1.5	37.5	0.1	95.9	2.1	12.5
	NITRITE NITROGEN	1	JANUARY	0.01	0.01	0.004	60	0.002	80	0.004	60
		2	MARCH	0.004	0.004	0.01	+	0.003	25	0.02	+
		3	APRIL	0.01	0.01	0.01	0	<0.002	80	0.01	0
		4	MAY	0.02	0.01	0.01	0	0.01	0	0.01	0
CATIONS	Ca	1	JANUARY	-	20	< 1	>95	4	80	20	0
		2	MARCH	30	17	<0.2	98.9	8	53	19	+
		3	APRIL	18	17	<0.2	98.9	6	64.8	16	5.9
		4	MAY	16	15	<0.2	98.7	8	46.7	15	0
	Mg	1	JANUARY	-	5	0.1	98	1.4	72	4	20
		2	MARCH	13	7	<0.1	98.6	1.4	80	7	0
		3	APRIL	-	6	<0.2	96.7	3.0	50	7	+
		4	MAY	7	6	< 0.2	96.7	3.0	50	6	0
	Zn	1	JANUARY	-	<0.04	<0.04		<0.04		<0.04	
		2	MARCH								
		3	APRIL	<0.02	<0.02	<0.02		<0.02		<0.02	
		4	MAY	0.04	<0.02	<0.02		<0.02		<0.02	
	K	1	JANUARY	-	1.4	0.2	85.8	1.0	28.6	3.5	+
		2	MARCH	1.2	1.2	0.3	75.0	0.3	75	3.6	+
		3	APRIL	1.5	1.4	0.1	92.9	0.3	78.6	3.5	+
		4	MAY	1.9	1.7	0.3	82.4	0.4	76.5	3.5	-

* Expressed as % reduction of filtered samples.   + Value of treated sample exceeds that of filtered control.   t Values reported are near limit of sensitivity for tes

APPENDIX I-IA

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION: FRENCH CREEK

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% ΔR*	CAPILLARY MEMBRANE DIALYSIS	% ΔR*	COAGULATION: ALUM POLY-ELECTROLYTE	% ΔR*
CATIONS	Na	1	JANUARY	-	7.1	58	+	1.9	73.3	7.1	0
		2	MARCH	10.7	10.7	52	+	2.2	79.5	11	+
		3	APRIL	10.1	10.4	31.5	+	6.3	67	10.2	1.9
		4	MAY	11.2	11.2	32	+	2.7	75.9	10.5	6.3
	B	1	JANUARY	0.1	0.08	0.02	75	0.04	50	0.04	50
		2	MARCH	0.1	0.1	0.02	80	0.02	80	0.1	0
		3	APRIL	0.11	0.09	0.03	66.7	0.01	88.9	0.05	16.7
		4	MAY	0.2	0.2	0.1	50	0.1	50	0.2	0
	Si	1	JANUARY	-	7.9	0.1	98.7	1.6	79.8	7.6	3.8
		2	MARCH	6.9	6.9	0.11	98.4	1.5	78.3	5.0	27.6
		3	APRIL	5.2	7.1	0.2	97.1	1.5	78.9	6.7	5.7
		4	MAY	16.0	15.0	0.24	98.4	3.74	75.1	14.1	6.0
	Co	1	JANUARY	-	<0.05	<0.05		<0.05		<0.05	
		2	MARCH	<0.05	<0.05	<0.05		<0.05		<0.05	
		3	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		4	MAY	<0.3	<0.3	<0.3		<0.3		<0.3	
	Cu	1	JANUARY	-	0.02	<0.02		<0.02		<0.02	
		2	MARCH	<0.05	<0.05	<0.05		<0.05		<0.05	
		3	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		4	MAY	<0.02	<0.02	<0.02		<0.02		<0.02	
	Fe	1	JANUARY	-	<0.02	<0.02		<0.02		<0.02	
		2	MARCH	0.3	<0.1	<0.1		<0.1		<0.1	
		3	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		4	MAY	0.7	<0.1	<0.1		<0.1		<0.1	
ANIONS	SO_3	1	JANUARY	<2	<2	<2		<2		<2	
		2	MARCH	<2	<2	<2		<2		<2	
		3	APRIL	<2	<2	<2		<2		<2	
		4	MAY	<2	<2	<2		<2		<2	

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for tes.

APPENDIX I-IA

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

FRENCH CREEK

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
ANIONS	SO_4	1	JANUARY	-	24	23	4.2	18	25	39	+
		2	MARCH	32	30	3	90	23	23.4	40	+
		3	APRIL	34	26	2	92.4	23	11.6	43	+
		4	MAY	33	33	0.1	99.7	14	57.6	40	+
	Cl	1	JANUARY	7	8	7	12.5	3	57.2	7	12.5
		2	MARCH	15	14	13	7.2	3	78.6	15	+
		3	APRIL	11	10	10	0	3	70	10	0
		4	MAY	12	11	12	8.4	1	8.4	11	0
MISCELLANEOUS ANALYSES	pH	1	JANUARY	-	7.14	10.57	-	6.49	-	6.92	-
		2	MARCH	6.92	7.30	10.96	-	7.00	-	7.30	-
		3	APRIL	6.89	6.80	10.22	-	6.60	-	6.60	-
		4	MAY	7.65	8.20	10.05	-	6.40	-	6.85	-
	SPECIFIC CONDUCTANCE	1	JANUARY	-	175	495	+	67	61.8	181	+
		2	MARCH	192	193	320	+	81	58.1	202	+
		3	APRIL	220	225	345	+	73	67.6	190	15.6
		4	MAY	187	190	190	0	82	56.9	190	0
	HARDNESS EDTA	1	JANUARY	-	42	<1	>97.6	14	66.7	37	12
		2	MARCH	58	57	<2	>96.5	43	24.6	53	7.1
		3	APRIL	48	59	<0.2	>99.6	11	81.4	43	27.1
		4	MAY	58	38	<1	>97.4	29	23.7	55	-
	ALKALINITY TOTAL	1	JANUARY	-	24	129	+	6	75	18	25
		2	MARCH	28	27	87	+	7	74.1	21	22.3
		3	APRIL	27	26	63	+	7	73.1	19	27
		4	MAY	28	27	87	+	7	74.1	21	22.3
	TOTAL SOLIDS	1	JANUARY	181	-	-	-	-	-	-	-
		2	MARCH	145	-	-	-	-	-	-	-
		3	APRIL	130	-	-	-	-	-	-	-
		4	MAY	148	-	-	-	-	-	-	-

* Expressed as % reduction of filtered samples + Value of treated sample exceeds that of filtered control. ‡ Values reported are near limit of sensitivity for tes

APPENDIX I-IA

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

FRENCH CREEK

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% ΔR*	CAPILLARY MEMBRANE DIALYSIS	% ΔR*	COAGULATION: ALUM POLY-ELECTROLYTE	% ΔR*
	DISSOLVED SOLIDS	1	JANUARY	-	183	535	+	79	56.9	184	+
		2	MARCH	-	131	241	+	59	55	143	+
		3	APRIL	-	132	254	+	47	64.4	129	2.3
		4	MAY	-	140	450	+	62	57.8	134	43
		1									
		2									
		3									
		4									
		1									
		2									
		3									
		4									
		1									
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		3									
		4									
		1									
		2									
		3									
		4									
		1									
		2									
		3									
		4									

* Expressed as % reduction of filtered samples. - Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for tes

APPENDIX I-IB

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

TROUT RUN

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
NUTRIENTS	TOTAL CARBON	1	JANUARY	31	30	11	63.4	8	73.4	26	13.4
		2	APRIL	28	29	13	55.2	17	41.4	26	10.4
		3	MAY	57	38	15	60.6	15	60.6	35	7.9
		4									
	ORGANIC CARBON	1	JANUARY	10	9	4	55.6	2	77.8	5	44.5
		2	APRIL	5	5	8	+	9	+	4	20
		3	MAY	16	7	4	42.9	5	28.6	5	28.6
		4									
	INORGANIC CARBON	1	JANUARY	21	21	7	66.7	6	71.5	21	0
		2	APRIL	23	24	5	79.2	7	70.9	22	8.[illegible]
		3	MAY	31	31	17	45.2	10	67.8	30	3.3
		4									
	TOTAL PO_4 - P	1	JANUARY	0.02	0.01	0.003	70	0.3	+	0.01	0
		2	APRIL	0.01	0.01	0.004	60	0.004	60	0.01	0
		3	MAY	0.02	0.02	<0.01	>50	<0.01	>50	0.04	+
		4									
	HYDROLYZ-ABLE PO_4 - P	1	JANUARY	0.02	0.01	0.01	0	0.3	+	0.01	0
		2	APRIL	0.01	0.01	0.01	0	0.003	70	0.01	-
		3	MAY	0.01	0.01	< 0.01	0	<0.01	0	0.04	+
		4									
	PHOSPHATE ORTHO	1	JANUARY	0.01	0.01	0.002	80	0.102	+	< 0.002	80
		2	APRIL	0.01	0.01	0.004	60	0.004	60	0.02	+
		3	MAY	0.01	0.01	< 0.01	0	< 0.01	0	0.003	70
		4									
	KJELDAHL NITROGEN	1	JANUARY	0.3	0.4	0.3	25	0.2	50	0.3	25
		2	APRIL	0.4	0.3	0.7	+	0.2	33.4	0.1	66.7
		3	MAY	0.1	0.2	2.9	+	0.2	0	0.7	+
		4									

* Expressed as % reduction of filtered samples. Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for tes

APPENDIX I-IB

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION: TROUT RUN

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
NUTRIENTS	AMMONIA NITROGEN	1	JANUARY	0.1	0.2	0.1	50	0.1	50	0.1	50
		2	APRIL	0.1	0.1	0.6	+	0.1	0	0.1	0
		3	MAY	0.1	0.1	2.9	+	0.1	0	0.1	0
		4									
	NITRATE NITROGEN	1	JANUARY	2.3	2.2	2.2	0	0.4	81.9	2.4	+
		2	APRIL	2.5	2.6	2.7	+	0.5	80.8	2.1	19.3
		3	MAY	2.0	1.8	0.3	83.4	0.4	77.8	1.0	44.5
		4									
	NITRITE NITROGEN	1	JANUARY	0.01	0.01	0.01	0	20.0	+	0.003	70
		2	APRIL	0.004	0.004	0.004	0	<0.002	50	0.01	+
		3	MAY	0.01	0.01	0.01	0	0.003	70	0.01	0
		4									
CATIONS	Ca	1	JANUARY	-	32	<0.2	>99.4	7	78.2	31	3.2
		2	APRIL	34	34	<0.2	>99.4	10	70.6	33	3
		3	MAY	35	35	<0.2	>99.5	20	42.9	33	5.8
		4									
	Mg	1	JANUARY	-	11	0.1	99.1	2	81.9	11	0
		2	APRIL	12	11	<0.2	98.2	4	63.7	10	9.1
		3	MAY	16	13	<0.2	98.5	5	61.6	12	7.7
		4									
	K	1	JANUARY	-	2	0.2	90	0.4	80	4	+
		2	APRIL	2	2	0.1	95	0.3	85	4	+
		3	MAY	2	2	0.3	85	0.3	85	4	+
		4									
	Na	1	JANUARY	-	6	71	+	1	83.4	6	0
		2	APRIL	8	6	33	+	5	16.7	6	0
		3	MAY	5	5	41	+	1	8	6	+
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control † Values reported are near limit of sensitivity for tes.

APPENDIX I-IB

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

TROUT RUN

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
CATIONS	B	1	JANUARY	0.1	0.1	0.1	0	0.02	80	0.1	0
		2	APRIL	0.1	0.1	0.04	60	0.02	80	0.04	60
		3	MAY	0.3	0.3	< 0.02	>93.4	0.1	66.7	0.2	33.4
		4									
	Si	1	JANUARY	3.5	3.4	0.2	94.2	0.6	82.4	2.9	14.8
		2	APRIL	0.1	0.1	0.04	60	0.02	80	0.04	60
		3	MAY	7.5	7.5	0.1	98.7	1.9	74.7	7.1	5.4
		4									
	Co	1	JANUARY	-	< 0.05	< 0.05		<0.05		< 0.05	
		2	APRIL	< .01	<0.1	<0.1		<0.1		<0.1	
		3	MAY	<0.3	<0.3	<0.3		<0.3		<0.3	
		4									
	Cu	1	JANUARY	-	0.02	0.02		0.02		0.02	
		2	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		3	MAY	<0.02	<0.02	<0.02		<0.02		<0.02	
		4									
	Zn	1	JANUARY	-	<0.04	<0.04		<0.04		<0.04	
		2	APRIL	0.04	0.03	< 0.02		0.03		0.02	
		3	MAY	<0.02	<0.02	<0.02		<0.02		<0.02	
		4									
	Fe	1	JANUARY	-	<0.02	<0.02		0.02		0.02	
		2	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		3	MAY	0.1	<0.1	<0.1		<0.1		<0.1	
		4									
ANIONS	SO_3	1	JANUARY	<0.2	<0.2	<0.2		<0.2		<0.2	
		2	APRIL	<0.2	<0.2	<0.2		<0.2		<0.2	
		3	MAY	<0.2	<0.2	<0.2		<0.2		<0.2	
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for tes

APPENDIX I-IB

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

TROUT RUN

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
ANIONS	SO_4	1	JANUARY	-	21	16	23.9	17	19.1	33	+
		2	APRIL	18	20	3	85	10	50	30	†+
		3	MAY	21	18	0.1	99.5	9	50	28	+
		4									
	Cl	1	JANUARY	21	19	8	57.9	3	84.3	10	47.4
		2	APRIL	11	11	11	0 .	2	81.9	11	0
		3	MAY	11	10	11	+	3	72.8	11	+
		4									
MISCELLANEOUS ANALYSES	pH	1	JANUARY	-	8.64	10.79	-	7.31	-	8.10	-
		2	APRIL	8.51	8.35	10.54	-	6.83	-	7.62	-
		3	MAY	7.60	8.25	10.20	-	7.30	-	7.65	-
		4									
	SPECIFIC CONDUCTANCE	1	JANUARY	-	98	137	+	22	77.6	93	5.2
		2	APRIL	93	93	65	30.2	23	75.3	87	6.5
		3	MAY	102	102	81	20.6	29	71.6	95	6.9
		4									
	HARDNESS - EDTA	1	JANUARY	-	112	< 1	>99.1	48	57.2	129	+
		2	APRIL	115	113	< 0.2	>99.8	31	72.6	109	3.6
		3	MAY	121	120	<1	>99.1	38	68.4	119	0.9
		4									
	ALKALINITY TOTAL	1	JANUARY	-	98	137	+	22	77.6	93	5.2
		2	APRIL	93	93	65	30.2	23	75.3	87	6.5
		3	MAY	102	102	81	20.6	29	71.6	95	6.9
		4									
	TOTAL SOLIDS	1	JANUARY	179	-	-	-	-	-	-	-
		2	APRIL	186	-	-	-	-	-	-	-
		3	MAY	217	-	-	-	-	-	-	-
		4									

* Expressed as % reduction of filtered control   + Value of treated sample exceeds that of filtered control   † Values reported are near limit of sensitivity for test

APPENDIX I-IB

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION;

TROUT RUN

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
MISC. ANALYSES	DISSOLVED SOLIDS	1	JANUARY	-	252	502	+	40	92.1	254	+
		2	APRIL	-	191	287	+	71	62.9	200	+
		3	MAY	-	236	410	+	200	15.3	199	15.7
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		1									
		2									
		3									
		4									
		1									
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		3									
		4									
		1									
		2									
		3									
		4									

* Expressed as % reduction of filtered samples.

+ Value of treated sample exceeds that of filtered control.

† Values reported are near limit of sensitivity for test

APPENDIX I-1C

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION;

VALLEY CREEK

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% ΔR*	CAPILLARY MEMBRANE DIALYSIS	% ΔR*	COAGULATION: ALUM POLY-ELECTROLYTE	% ΔR*
NUTRIENTS	TOTAL CARBON	1	JANUARY	43	43	21	51.2	11	74.5	43	0
		2	MARCH	44	43	6	86.1	8	81.4	45	+
		3	APRIL	34	41	9	78.1	13	68.3	39	4.9
		4	MAY	45	48	7	85.5	18	62.5	45	6.3
	ORGANIC CARBON	1	JANUARY	7	4	3	25	1	75	4	0
		2	MARCH	12	11	1	91	3	72.8	14	+
		3	APRIL	7	4	4	0	7	+	4	0
		4	MAY	5	4	1	75	2	50	10	+
	INORGANIC CARBON	1	JANUARY	36	39	18	53.9	10	74.4	39	0
		2	MARCH	32	32	5	84.4	5	84.4	31	3.2
		3	APRIL	27	37	5	86.5	6	83.8	35	5.5
		4	MAY	40	44	6	86.4	16	63.7	35	20.5
	TOTAL PO_4 - P	1	JANUARY	0.05	0.04	0.01	75	0.09	+	0.01	75
		2	MARCH	0.03	0.03	0.02	33.4	0.02	33.4	0.02	33.4
		3	APRIL	0.16	0.03	0.01	66.7	0.01	66.7	0.03	0
		4	MAY	0.03	0.02	< 0.01	>50.0	0.01	50	0.01	50
	HYDROLYZ-ABLE PO_4 - P	1	JANUARY	0.05	0.04	0.004	90	0.09	+	0.004	90
		2	MARCH	0.03	0.03	0.010	66.7	0.02	33.4	0.02	33.4
		3	APRIL	0.07	0.03	0.010	66.7	0.01	66.7	0.03	0
		4	MAY	0.03	0.02	< 0.010	>50	0.01	50	0.01	50
	PHOSPHATE ORTHO	1	JANUARY	0.04	0.03	<0.002	>93.4	0.04	+	0.006	80
		2	MARCH	0.02	0.02	<0.002	>90	0.01	50	0.01	50
		3	APRIL	0.03	0.03	0.002	93.4	0.01	66.7	0.03	0
		4	MAY	0.03	0.02	<0.005	>75	0.01	50	0.01	50
	KJELDAHL NITROGEN	1	JANUARY	0.2	0.2	0.2	0	0.1	50	0.2	0
		2	MARCH	0.2	0.2	1.9	+	0.2	0	0.6	+
		3	APRIL	0.3	0.3	1.0	+	0.1	66.7	0.2	33.4
		4	MAY	0.1	0.1	0.4	+	0.1	0	0.6	+

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for tes

APPENDIX I-C

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

VALLEY CREEK

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION ALUM POLY-ELECTROLYTE	% Δ R*
NUTRIENTS	AMMONIA NITROGEN	1	JANUARY	0.1	0.1	0.1	0	0.04	60	0.2	+
		2	MARCH	0.1	0.2	1.8	+	0.10	50	0.6	+
		3	APRIL	0.03	0.04	1.2	+	0.03	25	0.2	+
		4	MAY	0.04	0.10	0.4	+	0.10	0	0.6	+
	NITRATE NITROGEN	1	JANUARY	2.5	2.5	2.5	0	0.4	84	2.4	4
		2	MARCH	2.4	2.3	1.4	39.2	0.02	99.1	2.1	8.7
		3	APRIL	2.2	2.2	2.0	9.1	0.2	91	2.0	9.1
		4	MAY	-	-	-		-		-	
	NITRITE NITROGEN	1	JANUARY	0.02	0.02	0.01	50	0.004	80	0.01	50
		2	MARCH	0.02	0.02	0.02	0	< 0.001	95	0.02	0
		3	APRIL	0.01	0.01	0.01	0	< 0.002	80	0.01	0
		4	MAY	0.02	0.02	0.02	0	0.02	0	0.02	0
CATIONS	Ca	1	JANUARY	-	40	<0.2	>99.5	8	80	42	+
		2	MARCH	74	40	0.2	99.5	10	75	42	+
		3	APRIL	62	63	<0.2	>99.0	9	85.8	54	14.3
		4	MAY	33	36	<0.2	>99.5	11	69.5	38	+
	Mg	1	JANUARY	-	20	0.1	95.5	4	80	20	0
		2	MARCH	50	25	< 0.1	>99.6	4	84	24	4
		3	APRIL	20	17	<0.2	>98.9	4	76.5	21	+
		4	MAY	21	10	<0.2	>98	5		21	+
	Zn	1	JANUARY	-	<0.04	<0.04		<0.04		<0.04	
		2	MARCH	<0.02	<0.02	<0.02		<0.02		<0.02	
		3	APRIL	<0.02	<0.02	<0.02		<0.02		<0.02	
		4	MAY	<0.02	<0.02	<0.02		<0.02		<0.02	
	K	1	JANUARY	-	2	0.2	90	1.0	50	4	+
		2	MARCH	2	2	0.2	90	0.2	90	5	+
		3	APRIL	2	2	0.2	90	0.2	90	4	+
		4	MAY	2	2	0.3	85	1.0	50	4	+

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. t Values reported are near limit of sensitivity for te

APPENDIX I-C

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION;

VALLEY CREEK

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
CATIONS	Na	1	JANUARY	-	15	69	+	3	80	15	0
		2	MARCH	18	18	48	+	1	94.5	18	0
		3	APRIL	16	16	41	+	6	62.5	16	0
		4	MAY	17	17	32	+	3	82.4	17	0
	B	1	JANUARY	0.2	0.1	0.1	0	0.03	70	0.1	0
		2	MARCH	0.2	0.2	0.1	50	0.02	90	0.1	50
		3	APRIL	0.2	0.1	0.02	80	0.02	80	0.6	+
		4	MAY	0.6	0.6	<0.02	>96.7	0.1	83.4	0.3	50
	Si	1	JANUARY	3.3	3.0	0.1	96.7	0.6	80	2.9	3.4
		2	MARCH	2.3	0.4	0.3	25	0.1	75	2.3	+
		3	APRIL	1.0	2.6	0.1	96.2	0.5	80.8	2.0	23.1
		4	MAY	6.0	5.6	0.1	98.3	1.7	69.7	5.6	0
	Co	1	JANUARY	-	<0.05	<0.05	0	<0.05	0	<0.05	0
		2	MARCH	<0.05	<0.05	<0.05	0	<0.05	0	<0.05	0
		3	APRIL	<0.1	<0.1	<0.1	0	<0.1	0	<0.1	0
		4	MAY	<0.3	<0.3	<0.3	0	<0.3	0	<0.3	0
	Cu	1	JANUARY	-	0.02	0.02	0	0.02	0	0.02	0
		2	MARCH	<0.05	<0.05	<0.05	0	<0.05	0	<0.05	0
		3	APRIL	<0.1	<0.1	<0.1	0	<0.1	0	<0.1	0
		4	MAY	<0.3	<0.3	<0.3	0	<0.3	0	<0.3	0
	Fe	1	JANUARY	-	<0.02	<0.02		<0.02		<0.02	
		2	MARCH	0.3	<0.1	<0.1		<0.1		<0.1	
		3	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		4	MAY	0.74	<0.1	<0.1		<0.1		<0.1	
ANIONS	SO_3	1	JANUARY	<2	<2	<2		<2		<2	
		2	MARCH	<2	<2	<2		<2		<2	
		3	APRIL	<2	<2	<2		<2		<2	
		4	MAY	<2	<2	<2		<2		<2	

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for te

APPENDIX I-C

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION;

VALLEY CREEK

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION ALUM POLY-ELECTROLYTE	% Δ R*
ANIONS	SO_4	1	JANUARY	-	38	6	84.2	17	44.7	44	+
		2	MARCH	31	30	< 1	>96.7	12	60	40	+
		3	APRIL	34	30	3	90	8	73.4	41	+
		4	MAY	33	34	<1	>97.1	15	55.9	41	+
	Cl	1	JANUARY	29	29	24	17.3	6.5	77.6	12.5	56.9
		2	MARCH	30	30	22	26.7	3.6	12	30.0	0
		3	APRIL	-	-	-		-		-	-
		4	MAY	29	29	29	0	5.0	82.8	28.0	3.5
MISECELLANEOUS ANALYSES	pH	1	JANUARY	-	8.95	11.25	-	7.14	-	9.38	-
		2	MARCH	7.00	8.30	7.75	-	7.02	-	11.09	-
		3	APRIL	9.03	8.77	10.22	-	6.89	-	8.38	-
		4	MAY	8.35	8.40	9.70	-	6.95	-	8.10	-
	SPECIFIC CONDUCTANCE	1	JANUARY	-	505	495	2	140	72.3	495	2
		2	MARCH	490	495	290	41.5	78	84.3	487	1.7
		3	APRIL	500	480	405	15.7	83	82.8	480	+
		4	MAY	490	485	175	64	150	69.1	482	0.7
	HARDNESS EDTA	1	JANUARY	-	192	<1	>99.5	44	77.1	183	4.7
		2	MARCH	206	-	< 2	-	31	-	205	-
		3	APRIL	168	177	<0.2	>99.8	24	86.5	169	+
		4	MAY	176	178	<1	>99.4	53	70.3	173	2.9
	ALKALINITY TOTAL	1	JANUARY	-	168	111	34	35	79.2	154	8.4
		2	MARCH	168	165	61	63.1	17	89.7	154	6.7
		3	APRIL	146	146	74	49.4	20	86.4	137	6.2
		4	MAY	153	151	24	84.2	38	74.9	139	8.0
	TOTAL SOLIDS	1	JANUARY	348	-	-	-	-	-	-	-
		2	MARCH	340	-	-	-	-	-	-	-
		3	APRIL	350	-	-	-	-	-	-	-
		4	MAY	520	-	-	-	-	-	-	-

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for test

APPENDIX I-C

COMPARATIVE ANALYSIS OF STREAM WATER BEFORE AND AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

VALLEY CREEK

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% ΔR*	CAPILLARY MEMBRANE DIALYSIS	% ΔR*	COAGULATION: ALUM POLY-ELECTROLYTE	% ΔR*
MISC. ANALYSES	DISSOLVED SOLIDS	1	JANUARY	-	344	478	28.1	113	67.2	372	+
		2	MARCH	-	299	242	19.1	120	59.9	295	1.4
		3	APRIL	-	308	236	23.4	59	80.9	295	4.3
		4	MAY	-	463	375	19.1	224	51.7	292	37
		1									
		2									
		3									
		4									
		1									
		2									
		3									
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		4									
		1									
		2									
		3									
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control † Values reported are near limit of sensitivity for tes

APPENDIX I-D

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION; PHOENIXVILLE

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
NUTRIENTS	TOTAL CARBON	1	MARCH	87	71	14	80.3	15	78	64	9.9
		2	APRIL	65	57	16	72.0	22	61.5	48	15.8
		3	MAY	84	75	14	81.4	37	50.7	58	22.7
		4									
	ORGANIC CARBON	1	MARCH	27	15	13	13.4	3	80.0	14	6.7
		2	APRIL	22	14	12	14.3	14	0	14	0
		3	MAY	25	19	8	57.9	24	+	12	36.9
		4									
	INORGANIC CARBON	1	MARCH	60	56	1	98.3	12	78.6	50	10.5
		2	APRIL	43	43	4	90.7	8	81.4	34	21.0
		3	MAY	59	56	6	89.3	13	76.8	46	17.9
		4									
	TOTAL PO_4 - P	1	MARCH	8	8	0.02	99.7	4	50.0	3	62.5
		2	APRIL	8	8	0.05	99.3	3	62.5	2	75.0
		3	MAY	8	7	0.03	99.5	3	57.2	1	85.5
		4									
	HYDROLYZABLE PO_4 - P	1	MARCH	8	8	0.02	99.7	4	50.0	3	62.5
		2	APRIL	8	8	0.04	99.5	3	62.5	2	75.0
		3	MAY	7	6	0.03	99.5	3	50.0	1	83.4
		4									
	PHOSPHATE ORTHO	1	MARCH	7	6	0.02	99.6	3	50.0	2	66.6
		2	APRIL	7	6	0.03	99.5	2	66.7	2	66.7
		3	MAY	3	3	0.03	99.0	3	0	0.1	96.7
		4									
	KJELDAHL NITROGEN	1	MARCH	29	25	0.6	97.6	4	84	26	+
		2	APRIL	31	29	2.0	93.2	-	-	26	10.4
		3	MAY	22	20	1.6	92.0	2	90	12	40.0
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for tes

APPENDIX I-D

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION; PHOENIXVILLE

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)								
				UNTREATED		TREATED						
				UNFILTERED	FILTERED	ALUMINA	% ΔR*	CAPILLARY MEMBRANE DIALYSIS	% ΔR*	COAGULATION: ALUM POLY-ELECTROLYTE	% ΔR*
NUTRIENTS	AMMONIA NITROGEN	1	MARCH	15	14	0.3	97.9	4	71.5	14	0
		2	APRIL	23	22	0.4	98.2	4	81.9	18	18.2
		3	MAY	21	18	0.1	99.5	1	94.5	11	38.9
		4									
	NITRATE NITROGEN	1	MARCH	0.1	0.1	0.1	0	0.03	70.0	0.1	0
		2	APRIL	0.1	0.1	0.2	+	0.1	0	0.2	-
		3	MAY	0.2	0.2	0.1	50.0	0.2	0	0.1	50.0
		4									
	NITRITE NITROGEN	1	MARCH	0.01	0.01	0.01	0	0.002	80.0	0.01	0
		2	APRIL	0.09	0.08	0.08	0	0.01	87.5	[illegible]	[illegible]
		3	MAY	0.03	0.02	0.02	0	0.01	50.0	[illegible]	+
		4									
CATIONS	Ca	1	MARCH	120	67	<0.2	99.7	22	65.7	58	[illegible]
		2	APRIL	80	52	<0.2	99.6	16	69.3	[illegible]	27.[illegible]
		3	MAY	50	33	<0.2	99.4	11	66.7	35	+
		4									
	Mg	1	MARCH	27	15	<0.1	99.4	5	66.7	11	6.[illegible]
		2	APRIL	12	12	<0.2	98.4	4	66.7	[illegible]	16.[illegible]
		3	MAY	13	13	<0.2	98.5	4	69.2	13	0
		4									
	Zn	1	MARCH	0.07	0.03	<0.02		0.03		0.03	
		2	APRIL	0.08	0.05	< 0.02		0.05		0.03	
		3	MAY	0.2	0.02	0.02		0.04		0.03	
		4									
	K	1	MARCH	21	21	0.3	98.6	3	85.8	36	+
		2	APRIL	16	15	0.3	98.0	3	80.0	25	+
		3	MAY	1.7	17	5	70.6	4	76.5	28	+
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. ‡ Values reported are near limit of sensitivity for te

APPENDIX I-D

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION: PHOENIXVILLE

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
CATIONS	Na	1	MARCH	80	77	81	+	15	80.6	77	0
		2	APRIL	66	61	48	21.4	14	77.1	60	1.7
		3	MAY	77	78	57	27.0	18	77.0	77	1.3
		4									
	B	1	MARCH	0.6	0.5	0.1	80.0	0.2	60.0	0.6	+
		2	APRIL	0.9	0.8	0.1	87.5	0.1	87.5	0.8	0
		3	MAY	2.2	1.7	0.2	88.3	0.7	58.9	2.0	+
		4									
	Si	1	MARCH	7.0	6.0	0.1	98.4	1.4	76.7	4.0	33.4
		2	APRIL	6.4	5.3	0.2	96.3	1.2	77.4	5.5	+
		3	MAY	12.0	11.0	1.0	91	3.0	72.8	16.0	+
		4									
	Co	1	MARCH	<0.05	<0.05	<0.05		<0.05		<0.05	
		2	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		3	MAY	<0.3	<0.3	<0.3		<0.3		<0.3	
		4									
	Cu	1	MARCH	<0.1	<0.1	<0.1		<0.1		<0.1	
		2	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		3	MAY	0.03	<0.02	<0.02		<0.02		<0.02	
		4									
	Fe	1	APRIL	<0.1	<0.1	<0.1		<0.1		<0.1	
		2	MAY	0.4	<0.10	<0.10		<0.10		<0.10	
		3									
		4									
ANIONS	SO_3	1	MARCH	<2	<2	<2		<2		<2	
		2	APRIL	<2	<2	<2		<2		<2	
		3	MAY	<2	<2	<2		<2		<2	
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for tes

APPENDIX I-D

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION;

PHOENIXVILLE

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
ANIONS	SO₄	1	MARCH	133	122	8	99.3	55	54.9	169	†
		2	APRIL	119	113	6	94.7	49	56.7	154	†
		3	MAY	112	102	0.4	99.6	35	65.7	173	†
		4									
	Cl	1	MARCH	63	63	64	†	12	81	64	†
		2	APRIL	63	56	59	†	7	87.5	57	†
		3	MAY	72	71	80	†	13	81.7	45	36.7
		4									
MISCELLANEOUS ANALYSES	pH	1	MARCH	7.61	8.05	10.96	-	7.85	-	7.78	-
		2	APRIL	7.72	7.68	9.78	-	7.30	-	7.76	-
		3	MAY	7.95	8.05	9.25	-	7.85	-	7.90	-
		4									
	SPECIFIC CONDUCTANCE	1	MARCH	1000	1020	495	51.5	250	75.5	1040	†
		2	APRIL	825	815	420	48.5	195	76.1	820	†
		3	MAY	890	860	360	58.2	275	68.1	880	†
		4									
	HARDNESS - EDTA	1	MARCH	191	188	<2	>98.9	62	67.1	177	5.9
		2	APRIL	121	120	<0.2	>99.8	38	68.4	116	3.4
		3	MAY	156	157	<1.0	99.3	62	60.6	146	7.1
		4									
	ALKALINITY - TOTAL	1	MARCH	260	255	75	70.6	69	73.0	226	11.4
		2	APRIL	177	176	38	78.5	32	81.9	137	21.6
		3	MAY	211	207	13	93.8	53	74.4	161	22.3
		4									
	TOTAL SOLIDS	1	MARCH	340	-	-	-	-	-	-	-
		2	APRIL	406	-	-	-	-	-	-	-
		3	MAY	715	-	-	-	-	-	-	-
		4									

* Expressed as % reduction of filtered samples.   - Value of treated sample exceeds that of filtered control.   † Values reported are near limit of sensitivity for tes

APPENDIX I-D

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

PHOENIXVILLE

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
MISC. ANALYSES	DISSOLVED SOLIDS	1	MARCH	-	497	390	21.6	144	71.1	512	+
		2	APRIL	-	421	257	39.0	114	73.0	209	50.4
		3	MAY	-	150	317	51.3	167	74.4	496	23.7
		4									
		1									
		2									
		3									
		4									
		1									
		2									
		3									
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		4									
		1									
		2									
		3									
		4									
		1									
		2									
		3									
		4									

* Expressed as % reduction of filtered samples.

+ Value of treated sample exceeds that of filtered control.

† Values reported are near limit of sensitivity for test

APPENDIX I-E

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION;

HATFIELD

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
NUTRIENTS	TOTAL CARBON	1	APRIL	73	72	19	73.7	23	68.1	67	7.0
		2	MAY	57	46	12	74.0	22	52.2	29	37.0
		3	JULY	26	27	8	70.4	18	73.4	26	3.8
		4									
	ORGANIC CARBON	1	APRIL	22	20	14	30.0	13	35.0	18	10.0
		2	MAY	21	10	6	40.0	9	10.0	8	20.0
		3	JULY	5	5	5	0	9	+	7	+
		4									
	INORGANIC CARBON	1	APRIL	51	52	5	90.4	10	80.8	49	5.8
		2	MAY	36	36	6	83.4	13	63.9	21	41.7
		3	JULY	21	22	3	41.7	9	59.1	19	13.7
		4									
	TOTAL PO_4 - P	1	APRIL	0.22	0.12	0.02	83.4	0.05	58.4	0.06	50.0
		2	MAY	0.21	0.16	0.01	93.8	0.09	43.8	<0.005	>96.9
		3	JULY	0.64	0.53	0.01	98.2	0.4	24.6	0.2	62.3
		4									
	HYDROLYZABLE PO_4 - P	1	APRIL	0.20	0.08	0.02	75.0	0.03	62.5	0.02	75.0
		2	MAY	0.20	0.16	0.01	93.8	0.09	43.8	< 0.01	>93.8
		3	JULY	0.63	0.54	0.01	98.2	0.35	35.2	0.17	68.6
		4									
	PHOSPHATE ORTHO	1	APRIL	0.09	0.05	0.002	96.0	0.02	60.0	0.01	80.0
		2	MAY	0.17	0.14	0.01	92.9	0.08	42.9	<0.005	> 96.5
		3	JULY	0.53	0.50	0.01	98.0	0.30	40.0	0.1	80.0
		4									
	KJEIDAHL NITROGEN	1	APRIL	70.2	57.0	10.0	82.5	-	-	50.2	12.0
		2	MAY	0.1	0.1	-	-	0.2	+	0.5	+
		3	JULY	1.8	1.3	1.7	+	1.2	7.7	1.3	0
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. t Values reported are near limit of sensitivity for test

APPENDIX I-E

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION; HATFIELD

				TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
NUTRIENTS	AMMONIA NITROGEN	1	APRIL	64.7	52.2	5.7	89.1	9.0	82.8	47.0	90.0
		2	MAY	0.1	0.1	4.4	+	0.1	0	0.2	+
		3	JULY	0.1	0.1	0.7	+	0.2	+	0.1	0
		4									
	NITRATE NITROGEN	1	APRIL	0.1	0.1	0.1	0	0.04	60.0	0.1	0
		2	MAY	1.7	1.6	1.5	6.3	<0.1	>93.8	1.5	6.3
		3	JULY	0.4	0.3	0.3	0	0.1	66.7	0.3	0
		4									
	NITRITE NITROGEN	1	APRIL	0.1	0.1	0.1	0	0.01	90.0	0.1	0
		2	MAY	4.1	4.3	4.1	4.7	1.1	74.5	4.1	4.7
		3	JULY	4.4	4.4	4.2	4.6	1.9	56.9	4.3	2.3
		4									
CATIONS	Ca	1	APRIL	87	58	<0.2	>99.6	37	36.3	57	1.8
		2	MAY	90	47	<0.2	>99.5	14	70.3	22	53.2
		3	JULY	55	57	1	98.2	31	45.7	55	3.6
		4									
	Mg	1	APRIL	9	6	<0.2	>96.7	4	33.4	6	0
		2	MAY	22	22	<0.2	>99.1	6	72.8	21	4.6
		3	JULY	14	14	1	92.9	8	42.9	14	0
		4									
	Zn	1	APRIL	0.04	0.03	<0.02	t	0.03	t	0.03	t
		2	MAY	0.16	0.02	0.02	t	0.04	t	0.03	t
		3	JULY	0.02	0.02	0.02	t	0.02	t	0.02	t
		4									
	K	1	APRIL	14	8	0.3	96.3	2	75.0	11	+
		2	MAY	6	6	16	+	2	66.7	19	+
		3	JULY	9	8	11	+	4	50.0	10	+
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. t Values reported are near limit of sensitivity for test

APPENDIX I-E

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

HATFIELD

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
CATIONS	Na	1	APRIL	60	58	83	+	14	75.9	51	12.1
		2	MAY	53	53	51	3.8	18	66.1	52	1.9
		3	JULY	58	62	60	3.3	32	48.4	59	4.9
		4									
	B	1	APRIL	0.9	0.9	0.1	88.9	0.1	88.9	0.5	44.5
		2	MAY	2.0	1.8	0.5	72.3	0.5	72.3	1.6	11.2
		3	JULY	1.0	1.0	0.2	80.0	0.1	90.0	0.5	50.0
		4									
	Si	1	APRIL	3.2	2.6	0.1	96.2	0.7	73.1	2.5	3.9
		2	MAY	12.0	12.0	0.2	98.4	4.3	64.2	10.0	16.7
		3	JULY	8.7	8.5	0.2	97.7	4.3	49.5	8.0	5.9
		4									
	Co	1	APRIL	<0.1	<0.1	<0.1	t	<0.1	t	<0.1	t
		2	MAY	<0.3	<0.3	<0.3	t	<0.3	t	<0.3	t
		3	JULY	0.05	0.05	0.05	t	0.05	t	0.05	t
		4									
	Cu	1	APRIL	<0.1	<0.1	<0.1	t	<0.1	t	<0.1	t
		2	MAY	<0.02	<0.02	<0.02	t	<0.02	t	<0.02	t
		3	JULY	0.02	0.02	0.02	t	0.02	t	0.02	t
		4									
	Fe	1	APRIL	<0.1	<0.1	<0.1	t	<0.1	t	<0.1	t
		2	MAY	<0.1	<0.1	<0.1	t	<0.1	t	<0.1	t
		3	JULY	0.09	0.08	0.02	t	0.06	t	0.06	t
		4									
ANIONS	SO_3	1	APRIL	<2	<2	<2	t	<2	t	<2	t
		2	MAY	<2	<2	<2	t	<2	t	<2	t
		3	JULY	<2	<2	<2	t	<2	t	<2	t
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. t Values reported are near limit of sensitivity for tes.

APPENDIX I-E

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION;

HATFIELD

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
ANIONS	SO_4	1	APRIL	357	352	4.8	98.4	131	62.8	350	0.6
		2	MAY	151	148	0.4	99.7	80	46.0	191	+
		3	JULY	118	118	2.3	98.1	85	28.0	122	• +
		4									
	Cl	1	APRIL	80	76	77	+	9	88.2	63	17.2
		2	MAY	57	60	62	+	16	73.4	57	5.0
		3	JULY	60	56	56	0	40	28.6	55	1.8
		4									
MISCELLANEOUS ANALYSES	pH	1	APRIL	7.84	7.76	9.73	-	7.39	-	7.81	-
		2	MAY	8.10	7.95	9.65	-	6.75	-	7.85	-
		3	JULY	7.98	7.89	9.45	-	7.81	-	8.70	-
		4									
	SPECIFIC CONDUCTANCE	1	APRIL	1530	1500	560	62.7	390	74	1430	4.7
		2	MAY	790	790	380	51.9	340	57	790	0
		3	JULY	652	660	610	33.0	409	38.1	661	+
		4									
	HARDNESS - EDTA	1	APRIL	261	256	<0.2	99.9	92	64.1	242	5.5
		2	MAY	255	256	<1	99.6	113	55.9	244	4.7
		3	JULY	180	178	4	97.7	106	40.5	180	+
		4									
	ALKALINITY TOTAL	1	APRIL	213	209	43	79.5	38	81.9	195	6.7
		2	MAY	114	114	32	72	43	62.3	66	42.2
		3	JULY	292	215	42	80.5	62	[illegible]1.2	101	53.1
		4									
	TOTAL SOLIDS	1	APRIL	666	-	-		-		-	
		2	MAY	490	-	-		-		-	
		3	JULY	433	-	-		-		-	
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for test

APPENDIX I-E

COMPARATIVE ANALYSIS OF WASTEWATER EFFLUENT BEFORE AFTER TREATMENT BY ALUMINA ADSORPTION; CAPILLARY MEMBRANE DIALYSIS; AND COAGULATION:

HATFIELD

CLASS	ANALYSIS	NO.	MONTH SAMPLE COLLECTED	TEST CONDITION/CONCENTRATION (PART PER MILLION)							
				UNTREATED		TREATED					
				UNFILTERED	FILTERED	ALUMINA	% Δ R*	CAPILLARY MEMBRANE DIALYSIS	% Δ R*	COAGULATION: ALUM POLY-ELECTROLYTE	% Δ R*
MISC. ANALYSES	DISSOLVED SOLIDS	1	APRIL	-	668	318	52.4	216	67.7	667	0.1
		2	MAY	-	499	407	18.5	225	34	526	+
		3	JULY	-	418	340	18.7	241	42.4	427	+
		4									
		1									
		2									
		3									
		4									
		1									
		2									
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		3									
		4									

* Expressed as % reduction of filtered samples. + Value of treated sample exceeds that of filtered control. † Values reported are near limit of sensitivity for tes

APPENDIX II

CAPILLARY MEMBRANE SPECIFICATIONS AND OPERATING CONDITIONS*

Composition	Cellulose
Temperature	Cellulose Fibers - 0 to 60°C
Particle Size	Avoid processing fluids containing particles larger than 10 .
Viscosity	Solutions as viscous as 59% sucrose in water at 0°C have been processed on the outside of the fibers and solutions as viscous as 43% sucrose in water at 0°C have been processed by flow through the fiber themselves.
Pressure and Vacuum	The devices should never be operated at a pressure differential greater than 600 mm Hg between the inside and outside of the fibers. If this differential is exceeded either by applying excess pressure or vacuum, the fibers may collapse and become permanently damaged.
Chemical Stability	Cellulose fibers have a normal operating range of pH 1-12. Contact with cellulose producing organisms, enzymes with cellulose activity and aromatic or chlorinated hydrocarbons should be avoided. Cellulose fibers are resistant to methanol, ethanol, isopropanol, 50% formamide in water, phosphate buffer at pH 8.0, 1M guanidine HCl and 6M urea.
Cleaning	Fibers can be cleaned of protein by soaking in an enzyme presoak or enzyme detergent. If the fibers become clogged, they normally can be cleaned by an overnight backflush with water, in the reverse direction of flow, using a pressure of 5 psi (0.3 atm).

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* Dow Chemical Company, Midland, Michigan.

Storage	To avoid possible bacterial degradation the fibers should be stored in a 1.5% formalin solution.
Special Precautions	Do not allow fibers to dry out once they have been wet. Rinse immediately after use and store as described above. Avoid touching the fibers. This is the most common cause of damage.